New Jersey
ACCUTEST
LABORATORIES

12/09/11

Technical Report for

Arcadis

Ringwood, NJ

NJ000604.0035

Accutest Job Number: JA89742

Sampling Date: 10/20/11

Report to:

Arcadis Geraghty & Miller

JRocklin@arcadis-us.com

ATTN: Jonathan Rocklin

Total number of pages in report: **30**

541567

ACCREDITED IN ACCORDANCE WITH nelac

Test results contained within this data package meet the requirements of the National Environmental Laboratory Accreditation Conference and/or state specific certification programs as applicable.

David N. Speis
VP, Laboratory Director

Client Service contact: Marie Meidhof 732-329-0200

Certifications: NJ(12129), NY(10983), CA, CT, DE, FL, IL, IN, KS, KY, LA, MA, MD, MI, MT, NC, PA, RI, SC, TN, VA, WV

Test results relate only to samples analyzed.

Sections: 1 2 3 4

Table of Contents

-1-

Sample Summary

Arcadis

Job No: JA89742

Ringwood, NJ
Project No: NJ000604.0035

Sample Number	Collected Date	Time	By	Received	Matrix Code	Type	Client Sample ID
JA89742-1	10/20/11	12:00	JR	10/20/11	AQ	Field Blank Soil	PMPAIRSHAFT-FB-102011
JA89742-2	10/20/11	15:00	JR	10/20/11	SO	Soil	PMPAIRSHAFT-SED-102011
JA89742-3	10/20/11	15:00	JR	10/20/11	AQ	Trip Blank Soil	TB102011

Soil samples reported on a dry weight basis unless otherwise indicated on result page.

CASE NARRATIVE / CONFORMANCE SUMMARY

Client: Arcadis **Job No** JA89742

Site: Ringwood, NJ **Report Date** 12/9/2011 9:49:03 AM

On 10/20/2011, 1 Sample(s), 1 Trip Blank(s) and 1 Field Blank(s) were received at Accutest Laboratories at a temperature of 1 C. Samples were intact and chemically preserved, unless noted below. An Accutest Job Number of JA89742 was assigned to the project. Laboratory sample ID, client sample ID and dates of sample collection are detailed in the report's Results Summary Section.

Specified quality control criteria were achieved for this job except as noted below. For more information, please refer to the analytical results and QC summary pages.

Volatiles by GCMS By Method SW846 8260B

Matrix: AQ **Batch ID:** V2C4029

- All samples were analyzed within the recommended method holding time.
- Sample(s) JA89796-3MS, JA89796-8DUP were used as the QC samples indicated.
- All method blanks for this batch meet method specific criteria.
- Matrix Spike Recovery(s) for 1,1,2,2-Tetrachloroethane, 1,1,2-Trichloroethane, 1,2-Dibromo-3-chloropropane, 2-Hexanone, 4-Methyl-2-pentanone(MIBK) are outside control limits. Probable cause due to matrix interference.

Matrix: SO **Batch ID:** VG6694

- All samples were analyzed within the recommended method holding time.
- Sample(s) JA89997-1MS, JA89997-1MSD were used as the QC samples indicated.
- All method blanks for this batch meet method specific criteria.

Extractables by GCMS By Method SW846 8270D

Matrix: AQ **Batch ID:** OP52651

- All samples were extracted within the recommended method holding time.
- Sample(s) JA89461-1MS, JA89461-1MSD were used as the QC samples indicated.
- All method blanks for this batch meet method specific criteria.
- Matrix Spike Recovery(s) for 4-Nitrophenol are outside control limits. Outside control limits due to matrix interference.
- Matrix Spike Duplicate Recovery(s) for 4-Nitrophenol are outside control limits. Probable cause due to matrix interference.

Matrix: SO **Batch ID:** OP52738

- All samples were extracted within the recommended method holding time.
- All method blanks for this batch meet method specific criteria.
- Sample(s) JA89742-2MS, JA89742-2MSD were used as the QC samples indicated.
- RPD(s) for MSD for 3,3'-Dichlorobenzidine, Hexachlorocyclopentadiene are outside control limits for sample OP52738-MSD. Outside control limits due to matrix interference.

Extractables by GCMS By Method SW846 8270D BY SIM

Matrix: AQ	**Batch ID:** OP52651A

- All samples were extracted within the recommended method holding time.
- All method blanks for this batch meet method specific criteria.
- Sample(s) JA89461-1MS, JA89461-1MSD were used as the QC samples indicated.

Matrix: SO	**Batch ID:** OP52738A

- All samples were extracted within the recommended method holding time.
- Sample(s) JA89742-2MS, JA89742-2MSD were used as the QC samples indicated.
- All method blanks for this batch meet method specific criteria.

Extractables by GC By Method SW846 8082A

Matrix: AQ	**Batch ID:** OP52699

- All samples were extracted within the recommended method holding time.
- Sample(s) JA89735-1MS, JA89735-1MSD, OP52699-MSMSD were used as the QC samples indicated.
- All method blanks for this batch meet method specific criteria.

Matrix: SO	**Batch ID:** OP53090

- All method blanks for this batch meet method specific criteria.
- Sample(s) JA91885-1MS, JA91885-1MSD, OP53090-MSMSD were used as the QC samples indicated.
- The following samples were extracted outside of holding time for method SW846 8082A: JA89742-2 Re-extracted due to lab contaminated on original extract. originally prep date was within holding time.
- RPD(s) for MSD for Aroclor 1016, Aroclor 1242 are outside control limits for sample OP53090-MSD. Outside control limits due to matrix interference.
- JA89742-2: Re-extracted due to lab contaminated on original extract. originally prep date was within holding time.

Metals By Method SW846 6010C

Matrix: AQ	Batch ID: MP61019

- All samples were digested within the recommended method holding time.
- All method blanks for this batch meet method specific criteria.
- Sample(s) JA89538-1MS, JA89538-1MSD, JA89538-1SDL were used as the QC samples for metals.
- Matrix Spike Recovery(s) for Manganese, Iron are outside control limits. Spike amount low relative to the sample amount. Refer to lab control or spike blank for recovery information.
- RPD(s) for Serial Dilution for Aluminum, Cadmium, Copper, Lead, Nickel, Selenium, Vanadium, Zinc are outside control limits for sample MP61019-SD1. Percent difference acceptable due to low initial sample concentration (< 50 times IDL).
- MP61019-SD1 for Manganese: Serial dilution indicates possible matrix interference.

Matrix: SO	Batch ID: MP61185

- All samples were digested within the recommended method holding time.
- All samples were digested within the recommended method holding time.
- All method blanks for this batch meet method specific criteria.
- All method blanks for this batch meet method specific criteria.
- Sample(s) JA89742-2MS, JA89742-2MSD, JA89742-2PS, JA89742-2SDL were used as the QC samples for metals.
- Matrix Spike Recovery(s) for Aluminum, Antimony, Chromium, Cobalt, Potassium, Selenium, Silver, Vanadium, Zinc are outside control limits. Spike recovery indicates possible matrix interference and/or sample nonhomogeneity.
- Matrix Spike Duplicate Recovery(s) for Aluminum, Antimony, Barium, Chromium, Cobalt, Copper, Magnesium, Manganese, Potassium, Selenium, Vanadium, Zinc are outside control limits. Probable cause due to matrix interference.
- Matrix Spike Recovery(s) for Calcium are outside control limits. Spike amount low relative to the sample amount. Refer to lab control or spike blank for recovery information.
- RPD(s) for Serial Dilution for Antimony, Sodium, Aluminum, Barium, Calcium, Chromium, Cobalt, Iron, Magnesium, Manganese, Potassium, Vanadium, Zinc are outside control limits for sample MP61185-SD1. Percent difference acceptable due to low initial sample concentration (< 50 times IDL).
- MP61185-MB1 for Chromium: All reported results <RL or >10x MB value.
- MP61185-SD1 for Barium: Serial dilution indicates possible matrix interference.
- JA89742-2 for Sodium: Elevated detection limit due to dilution required for matrix interference (indicated by failing internal standard on original analysis).
- MP61185-PS1 for Manganese: Spike recovery indicates possible matrix interference.
- MP61185-SD1 for Aluminum: Serial dilution indicates possible matrix interference.
- MP61185-SD1 for Calcium: Serial dilution indicates possible matrix interference.
- MP61185-SD1 for Iron: Serial dilution indicates possible matrix interference.
- JA89742-2 for Potassium: Elevated detection limit due to dilution required for matrix interference (indicated by failing internal standard on original analysis).
- MP61185-SD1 for Potassium: Serial dilution indicates possible matrix interference.
- MP61185-SD1 for Cobalt: Serial dilution indicates possible matrix interference.
- MP61185-PS1 for Vanadium: Spike recovery indicates possible matrix interference.
- MP61185-SD1 for Magnesium: Serial dilution indicates possible matrix interference.
- MP61185-SD1 for Vanadium: Serial dilution indicates possible matrix interference.
- MP61185-PS1 for Aluminum: Spike recovery indicates possible matrix interference.
- MP61185-PS1 for Iron: Spike recovery indicates possible matrix interference.
- JA89742-2 for Aluminum: Elevated detection limit due to dilution required for matrix interference (indicated by failing internal standard on original analysis).
- JA89742-2 for Calcium: Elevated detection limit due to dilution required for matrix interference (indicated by failing internal standard on original analysis).
- MP61185-PS1 for Silver: Spike recovery indicates possible matrix interference.

Metals By Method SW846 6010C

Matrix: SO	Batch ID: MP61185

- JA89742-2 for Iron: Elevated detection limit due to dilution required for matrix interference (indicated by failing internal standard on original analysis).
- MP61185-PS1 for Barium: Spike recovery indicates possible matrix interference.
- MP61185-PS1 for Beryllium: Spike recovery indicates possible matrix interference.
- MP61185-SD1 for Manganese: Serial dilution indicates possible matrix interference.
- JA89742-2 for Magnesium: Elevated detection limit due to dilution required for matrix interference (indicated by failing internal standard on original analysis).
- MP61185-PS1 for Zinc: Spike recovery indicates possible matrix interference.
- MP61185-PS1 for Cobalt: Spike recovery indicates possible matrix interference.
- MP61185-SD1 for Chromium: Serial dilution indicates possible matrix interference.
- MP61185-PS1 for Copper: Spike recovery indicates possible matrix interference.
- MP61185-SD1 for Zinc: Serial dilution indicates possible matrix interference.

Metals By Method SW846 6020A

Matrix: AQ	Batch ID: MP61019A

- All samples were digested within the recommended method holding time.
- All method blanks for this batch meet method specific criteria.
- Sample(s) JA89538-1MS, JA89538-1MSD, JA89538-1SDL were used as the QC samples for metals.
- RPD(s) for Serial Dilution for Arsenic are outside control limits for sample MP61019A-SD1. Percent difference acceptable due to low initial sample concentration (< 50 times IDL).

Matrix: SO	Batch ID: MP61185A

- All samples were digested within the recommended method holding time.
- All method blanks for this batch meet method specific criteria.
- Sample(s) JA89742-2MS, JA89742-2MSD, JA89742-2SDL were used as the QC samples for metals.
- RPD(s) for Serial Dilution for Arsenic are outside control limits for sample MP61185A-SD1. Probable cause due to sample homogeneity.
- MP61185A-SD1 for Arsenic: Serial dilution indicates possible matrix interference.

Metals By Method SW846 7470A

Matrix: AQ	Batch ID: MP61173

- All samples were digested within the recommended method holding time.
- All method blanks for this batch meet method specific criteria.
- Sample(s) JA89526-1MS, JA89526-1MSD were used as the QC samples for metals.

Metals By Method SW846 7471B

Matrix: SO	Batch ID: MP61187

- All samples were digested within the recommended method holding time.
- All method blanks for this batch meet method specific criteria.
- Sample(s) JA89867-2RMS, JA89867-2RMSD were used as the QC samples for metals.

Wet Chemistry By Method SM18 2540G

Matrix: SO	Batch ID: GN57872

- The data for SM18 2540G meets quality control requirements.

Accutest certifies that data reported for samples received, listed on the associated custody chain or analytical task order, were produced to specifications meeting Accutest's Quality System precision, accuracy and completeness objectives except as noted.

Estimated non-standard method measurement uncertainty data is available on request, based on quality control bias and implicit for standard methods. Acceptable uncertainty requires tested parameter quality control data to meet method criteria.

Accutest Laboratories is not responsible for data quality assumptions if partial reports are used and recommends that this report be used in its entirety. Data release is authorized by Accutest Laboratories indicated via signature on the report cover

New Jersey
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Sample Results

Report of Analysis

Report of Analysis

Client Sample ID:	PMPAIRSHAFT-FB-102011		
Lab Sample ID:	JA89742-1	**Date Sampled:**	10/20/11
Matrix:	AQ - Field Blank Soil	**Date Received:**	10/20/11
Method:	SW846 8260B	**Percent Solids:**	n/a
Project:	Ringwood, NJ		

	File ID	DF	Analyzed	By	Prep Date	Prep Batch	Analytical Batch
Run #1	2C88297.D	1	10/25/11	DR	n/a	n/a	V2C4029
Run #2							

	Purge Volume
Run #1	5.0 ml
Run #2	

VOA TCL List (OLM4.2)

CAS No.	Compound	Result	RL	MDL	Units	Q
67-64-1	Acetone	ND	10	7.6	ug/l	
71-43-2	Benzene	ND	1.0	0.22	ug/l	
75-27-4	Bromodichloromethane	ND	1.0	0.23	ug/l	
75-25-2	Bromoform	ND	4.0	0.24	ug/l	
74-83-9	Bromomethane	ND	2.0	0.31	ug/l	
78-93-3	2-Butanone (MEK)	ND	10	2.9	ug/l	
75-15-0	Carbon disulfide	ND	2.0	0.18	ug/l	
56-23-5	Carbon tetrachloride	ND	1.0	0.19	ug/l	
108-90-7	Chlorobenzene	ND	1.0	0.22	ug/l	
75-00-3	Chloroethane	ND	1.0	0.37	ug/l	
67-66-3	Chloroform	ND	1.0	0.21	ug/l	
74-87-3	Chloromethane	ND	1.0	0.22	ug/l	
110-82-7	Cyclohexane	ND	5.0	0.29	ug/l	
96-12-8	1,2-Dibromo-3-chloropropane	ND	10	1.3	ug/l	
124-48-1	Dibromochloromethane	ND	1.0	0.20	ug/l	
106-93-4	1,2-Dibromoethane	ND	2.0	0.21	ug/l	
95-50-1	1,2-Dichlorobenzene	ND	1.0	0.18	ug/l	
541-73-1	1,3-Dichlorobenzene	ND	1.0	0.29	ug/l	
106-46-7	1,4-Dichlorobenzene	ND	1.0	0.26	ug/l	
75-71-8	Dichlorodifluoromethane	ND	5.0	0.31	ug/l	
75-34-3	1,1-Dichloroethane	ND	1.0	0.19	ug/l	
107-06-2	1,2-Dichloroethane	ND	1.0	0.18	ug/l	
75-35-4	1,1-Dichloroethene	ND	1.0	0.28	ug/l	
156-59-2	cis-1,2-Dichloroethene	ND	1.0	0.22	ug/l	
156-60-5	trans-1,2-Dichloroethene	ND	1.0	0.31	ug/l	
78-87-5	1,2-Dichloropropane	ND	1.0	0.22	ug/l	
10061-01-5	cis-1,3-Dichloropropene	ND	1.0	0.22	ug/l	
10061-02-6	trans-1,3-Dichloropropene	ND	1.0	0.19	ug/l	
100-41-4	Ethylbenzene	ND	1.0	0.21	ug/l	
76-13-1	Freon 113	ND	5.0	0.49	ug/l	
591-78-6	2-Hexanone	ND	5.0	3.0	ug/l	
98-82-8	Isopropylbenzene	ND	2.0	0.19	ug/l	

ND = Not detected MDL - Method Detection Limit J = Indicates an estimated value
RL = Reporting Limit B = Indicates analyte found in associated method blank
E = Indicates value exceeds calibration range N = Indicates presumptive evidence of a compound

Report of Analysis

Client Sample ID:	PMPAIRSHAFT-FB-102011		
Lab Sample ID:	JA89742-1	**Date Sampled:**	10/20/11
Matrix:	AQ - Field Blank Soil	**Date Received:**	10/20/11
Method:	SW846 8260B	**Percent Solids:**	n/a
Project:	Ringwood, NJ		

VOA TCL List (OLM4.2)

CAS No.	Compound	Result	RL	MDL	Units	Q
79-20-9	Methyl Acetate	ND	5.0	2.9	ug/l	
108-87-2	Methylcyclohexane	ND	5.0	0.18	ug/l	
1634-04-4	Methyl Tert Butyl Ether	ND	1.0	0.18	ug/l	
108-10-1	4-Methyl-2-pentanone(MIBK)	ND	5.0	1.2	ug/l	
75-09-2	Methylene chloride	ND	2.0	0.20	ug/l	
100-42-5	Styrene	ND	5.0	0.23	ug/l	
79-34-5	1,1,2,2-Tetrachloroethane	ND	1.0	0.20	ug/l	
127-18-4	Tetrachloroethene	ND	1.0	0.32	ug/l	
108-88-3	Toluene	ND	1.0	0.15	ug/l	
120-82-1	1,2,4-Trichlorobenzene	ND	5.0	0.15	ug/l	
71-55-6	1,1,1-Trichloroethane	ND	1.0	0.24	ug/l	
79-00-5	1,1,2-Trichloroethane	ND	1.0	0.23	ug/l	
79-01-6	Trichloroethene	ND	1.0	0.21	ug/l	
75-69-4	Trichlorofluoromethane	ND	5.0	0.35	ug/l	
75-01-4	Vinyl chloride	ND	1.0	0.27	ug/l	
1330-20-7	Xylene (total)	ND	1.0	0.17	ug/l	

CAS No.	Surrogate Recoveries	Run# 1	Run# 2	Limits
1868-53-7	Dibromofluoromethane	99%		77-120%
17060-07-0	1,2-Dichloroethane-D4	89%		70-127%
2037-26-5	Toluene-D8	99%		79-120%
460-00-4	4-Bromofluorobenzene	92%		76-118%

CAS No.	Tentatively Identified Compounds	R.T.	Est. Conc.	Units	Q
	Total TIC, Volatile		0	ug/l	

ND = Not detected MDL - Method Detection Limit J = Indicates an estimated value
RL = Reporting Limit B = Indicates analyte found in associated method blank
E = Indicates value exceeds calibration range N = Indicates presumptive evidence of a compound

Report of Analysis

Client Sample ID:	PMPAIRSHAFT-FB-102011		
Lab Sample ID:	JA89742-1	**Date Sampled:**	10/20/11
Matrix:	AQ - Field Blank Soil	**Date Received:**	10/20/11
Method:	SW846 8270D SW846 3510C	**Percent Solids:**	n/a
Project:	Ringwood, NJ		

	File ID	DF	Analyzed	By	Prep Date	Prep Batch	Analytical Batch
Run #1	F10069.D	1	10/27/11	NAP	10/24/11	OP52651	EF4655
Run #2							

	Initial Volume	Final Volume
Run #1	1000 ml	1.0 ml
Run #2		

ABN TCL List

CAS No.	Compound	Result	RL	MDL	Units	Q
95-57-8	2-Chlorophenol	ND	5.0	0.97	ug/l	
59-50-7	4-Chloro-3-methyl phenol	ND	5.0	1.8	ug/l	
120-83-2	2,4-Dichlorophenol	ND	5.0	1.2	ug/l	
105-67-9	2,4-Dimethylphenol	ND	5.0	1.5	ug/l	
51-28-5	2,4-Dinitrophenol	ND	20	17	ug/l	
534-52-1	4,6-Dinitro-o-cresol	ND	20	0.99	ug/l	
95-48-7	2-Methylphenol	ND	2.0	1.0	ug/l	
	3&4-Methylphenol	ND	2.0	0.93	ug/l	
88-75-5	2-Nitrophenol	ND	5.0	1.5	ug/l	
100-02-7	4-Nitrophenol	ND	10	5.2	ug/l	
108-95-2	Phenol	ND	2.0	1.3	ug/l	
95-95-4	2,4,5-Trichlorophenol	ND	5.0	1.6	ug/l	
88-06-2	2,4,6-Trichlorophenol	ND	5.0	1.3	ug/l	
98-86-2	Acetophenone	ND	2.0	0.29	ug/l	
1912-24-9	Atrazine	ND	5.0	0.49	ug/l	
100-52-7	Benzaldehyde	ND	5.0	3.3	ug/l	
101-55-3	4-Bromophenyl phenyl ether	ND	2.0	0.36	ug/l	
85-68-7	Butyl benzyl phthalate	ND	2.0	0.29	ug/l	
92-52-4	1,1'-Biphenyl	ND	1.0	0.30	ug/l	
91-58-7	2-Chloronaphthalene	ND	2.0	0.30	ug/l	
106-47-8	4-Chloroaniline	ND	5.0	0.53	ug/l	
86-74-8	Carbazole	ND	1.0	0.36	ug/l	
105-60-2	Caprolactam	ND	2.0	0.69	ug/l	
111-91-1	bis(2-Chloroethoxy)methane	ND	2.0	0.31	ug/l	
111-44-4	bis(2-Chloroethyl)ether	ND	2.0	0.31	ug/l	
108-60-1	bis(2-Chloroisopropyl)ether	ND	2.0	0.45	ug/l	
7005-72-3	4-Chlorophenyl phenyl ether	ND	2.0	0.31	ug/l	
121-14-2	2,4-Dinitrotoluene	ND	2.0	0.43	ug/l	
606-20-2	2,6-Dinitrotoluene	ND	2.0	0.46	ug/l	
91-94-1	3,3'-Dichlorobenzidine	ND	5.0	0.36	ug/l	
132-64-9	Dibenzofuran	ND	5.0	0.27	ug/l	
84-74-2	Di-n-butyl phthalate	ND	2.0	0.56	ug/l	

ND = Not detected MDL - Method Detection Limit J = Indicates an estimated value
RL = Reporting Limit B = Indicates analyte found in associated method blank
E = Indicates value exceeds calibration range N = Indicates presumptive evidence of a compound

Report of Analysis

Client Sample ID:	PMPAIRSHAFT-FB-102011			
Lab Sample ID:	JA89742-1		**Date Sampled:**	10/20/11
Matrix:	AQ - Field Blank Soil		**Date Received:**	10/20/11
Method:	SW846 8270D SW846 3510C		**Percent Solids:**	n/a
Project:	Ringwood, NJ			

ABN TCL List

CAS No.	Compound	Result	RL	MDL	Units	Q
117-84-0	Di-n-octyl phthalate	ND	2.0	0.31	ug/l	
84-66-2	Diethyl phthalate	ND	2.0	0.33	ug/l	
131-11-3	Dimethyl phthalate	ND	2.0	0.28	ug/l	
117-81-7	bis(2-Ethylhexyl)phthalate	ND	2.0	0.59	ug/l	
87-68-3	Hexachlorobutadiene	ND	1.0	0.51	ug/l	
77-47-4	Hexachlorocyclopentadiene	ND	20	7.1	ug/l	
67-72-1	Hexachloroethane	ND	2.0	0.55	ug/l	
78-59-1	Isophorone	ND	2.0	0.27	ug/l	
91-57-6	2-Methylnaphthalene	ND	1.0	0.38	ug/l	
88-74-4	2-Nitroaniline	ND	5.0	1.1	ug/l	
99-09-2	3-Nitroaniline	ND	5.0	1.3	ug/l	
100-01-6	4-Nitroaniline	ND	5.0	1.7	ug/l	
98-95-3	Nitrobenzene	ND	2.0	0.42	ug/l	
621-64-7	N-Nitroso-di-n-propylamine	ND	2.0	0.30	ug/l	
86-30-6	N-Nitrosodiphenylamine	ND	5.0	0.31	ug/l	

CAS No.	Surrogate Recoveries	Run# 1	Run# 2	Limits
367-12-4	2-Fluorophenol	36%		10-83%
4165-62-2	Phenol-d5	22%		10-74%
118-79-6	2,4,6-Tribromophenol	126%		24-148%
4165-60-0	Nitrobenzene-d5	104%		38-129%
321-60-8	2-Fluorobiphenyl	96%		42-117%
1718-51-0	Terphenyl-d14	106%		14-132%

CAS No.	Tentatively Identified Compounds	R.T.	Est. Conc.	Units	Q
	Total TIC, Semi-Volatile		0	ug/l	

ND = Not detected　　MDL - Method Detection Limit　　J = Indicates an estimated value
RL = Reporting Limit　　B = Indicates analyte found in associated method blank
E = Indicates value exceeds calibration range　　N = Indicates presumptive evidence of a compound

Report of Analysis

Client Sample ID:	PMPAIRSHAFT-FB-102011		
Lab Sample ID:	JA89742-1	**Date Sampled:**	10/20/11
Matrix:	AQ - Field Blank Soil	**Date Received:**	10/20/11
Method:	SW846 8270D BY SIM SW846 3510C	**Percent Solids:**	n/a
Project:	Ringwood, NJ		

	File ID	DF	Analyzed	By	Prep Date	Prep Batch	Analytical Batch
Run #1	4M29528.D	1	11/08/11	NAP	10/24/11	OP52651A	E4M1256
Run #2							

	Initial Volume	Final Volume
Run #1	1000 ml	1.0 ml
Run #2		

CAS No.	Compound	Result	RL	MDL	Units	Q
87-86-5	Pentachlorophenol	ND	0.30	0.29	ug/l	
83-32-9	Acenaphthene	ND	0.10	0.014	ug/l	
208-96-8	Acenaphthylene	ND	0.10	0.016	ug/l	
120-12-7	Anthracene	ND	0.10	0.010	ug/l	
56-55-3	Benzo(a)anthracene	ND	0.10	0.015	ug/l	
50-32-8	Benzo(a)pyrene	ND	0.10	0.0049	ug/l	
205-99-2	Benzo(b)fluoranthene	ND	0.10	0.016	ug/l	
191-24-2	Benzo(g,h,i)perylene	ND	0.10	0.010	ug/l	
207-08-9	Benzo(k)fluoranthene	ND	0.10	0.013	ug/l	
218-01-9	Chrysene	ND	0.10	0.023	ug/l	
53-70-3	Dibenzo(a,h)anthracene	ND	0.10	0.023	ug/l	
206-44-0	Fluoranthene	ND	0.10	0.0096	ug/l	
86-73-7	Fluorene	ND	0.10	0.015	ug/l	
118-74-1	Hexachlorobenzene	ND	0.020	0.0080	ug/l	
193-39-5	Indeno(1,2,3-cd)pyrene	ND	0.10	0.011	ug/l	
91-20-3	Naphthalene	0.250	0.10	0.016	ug/l	
85-01-8	Phenanthrene	ND	0.10	0.016	ug/l	
129-00-0	Pyrene	ND	0.10	0.0081	ug/l	

CAS No.	Surrogate Recoveries	Run# 1	Run# 2	Limits
367-12-4	2-Fluorophenol	35%		10-100%
4165-62-2	Phenol-d5	22%		10-100%
118-79-6	2,4,6-Tribromophenol	85%		18-160%
4165-60-0	Nitrobenzene-d5	84%		32-135%
321-60-8	2-Fluorobiphenyl	68%		31-121%
1718-51-0	Terphenyl-d14	74%		10-130%

ND = Not detected MDL - Method Detection Limit J = Indicates an estimated value
RL = Reporting Limit B = Indicates analyte found in associated method blank
E = Indicates value exceeds calibration range N = Indicates presumptive evidence of a compound

Report of Analysis

Client Sample ID: PMPAIRSHAFT-FB-102011
Lab Sample ID: JA89742-1 **Date Sampled:** 10/20/11
Matrix: AQ - Field Blank Soil **Date Received:** 10/20/11
Method: SW846 8082A SW846 3510C **Percent Solids:** n/a
Project: Ringwood, NJ

	File ID	DF	Analyzed	By	Prep Date	Prep Batch	Analytical Batch
Run #1	XX112437.D	1	10/28/11	AZ	10/26/11	OP52699	GXX4209
Run #2							

	Initial Volume	Final Volume
Run #1	940 ml	1.0 ml
Run #2		

PCB List

CAS No.	Compound	Result	RL	MDL	Units	Q
12674-11-2	Aroclor 1016	ND	0.053	0.014	ug/l	
11104-28-2	Aroclor 1221	ND	0.053	0.029	ug/l	
11141-16-5	Aroclor 1232	ND	0.053	0.041	ug/l	
53469-21-9	Aroclor 1242	ND	0.053	0.0091	ug/l	
12672-29-6	Aroclor 1248	ND	0.053	0.015	ug/l	
11097-69-1	Aroclor 1254	ND	0.053	0.015	ug/l	
11096-82-5	Aroclor 1260	ND	0.053	0.022	ug/l	

CAS No.	Surrogate Recoveries	Run# 1	Run# 2	Limits
877-09-8	Tetrachloro-m-xylene	93%		27-144%
877-09-8	Tetrachloro-m-xylene	93%		27-144%
2051-24-3	Decachlorobiphenyl	60%		10-139%
2051-24-3	Decachlorobiphenyl	61%		10-139%

ND = Not detected MDL - Method Detection Limit J = Indicates an estimated value
RL = Reporting Limit B = Indicates analyte found in associated method blank
E = Indicates value exceeds calibration range N = Indicates presumptive evidence of a compound

Report of Analysis

Client Sample ID: PMPAIRSHAFT-FB-102011
Lab Sample ID: JA89742-1 **Date Sampled:** 10/20/11
Matrix: AQ - Field Blank Soil **Date Received:** 10/20/11
Percent Solids: n/a
Project: Ringwood, NJ

Total Metals Analysis

Analyte	Result	RL	MDL	Units	DF	Prep	Analyzed	By	Method	Prep Method
Aluminum	7.2 U	200	7.2	ug/l	1	10/31/11	11/01/11	BL	SW846 6010C [1]	SW846 3010A [4]
Antimony	1.3 U	6.0	1.3	ug/l	1	10/31/11	11/01/11	BL	SW846 6010C [1]	SW846 3010A [4]
Arsenic	0.18 B	1.0	0.093	ug/l	2	10/28/11	11/01/11	RP	SW846 6020A [2]	SW846 3010A [5]
Barium	0.70 B	200	0.44	ug/l	1	10/31/11	11/01/11	BL	SW846 6010C [1]	SW846 3010A [4]
Beryllium	0.24 U	1.0	0.24	ug/l	1	10/31/11	11/01/11	BL	SW846 6010C [1]	SW846 3010A [4]
Cadmium	0.17 U	3.0	0.17	ug/l	1	10/31/11	11/01/11	BL	SW846 6010C [1]	SW846 3010A [4]
Calcium	29.5 B	5000	9.0	ug/l	1	10/31/11	11/01/11	BL	SW846 6010C [1]	SW846 3010A [4]
Chromium	0.90 U	10	0.90	ug/l	1	10/31/11	11/01/11	BL	SW846 6010C [1]	SW846 3010A [4]
Cobalt	0.30 U	50	0.30	ug/l	1	10/31/11	11/01/11	BL	SW846 6010C [1]	SW846 3010A [4]
Copper	0.85 U	10	0.85	ug/l	1	10/31/11	11/01/11	BL	SW846 6010C [1]	SW846 3010A [4]
Iron	7.7 U	100	7.7	ug/l	1	10/31/11	11/01/11	BL	SW846 6010C [1]	SW846 3010A [4]
Lead	0.94 U	3.0	0.94	ug/l	1	10/31/11	11/01/11	BL	SW846 6010C [1]	SW846 3010A [4]
Magnesium	17 U	5000	17	ug/l	1	10/31/11	11/01/11	BL	SW846 6010C [1]	SW846 3010A [4]
Manganese	0.30 B	15	0.18	ug/l	1	10/31/11	11/01/11	BL	SW846 6010C [1]	SW846 3010A [4]
Mercury	0.075 U	0.20	0.075	ug/l	1	11/08/11	11/08/11	VK	SW846 7470A [3]	SW846 7470A [6]
Nickel	0.41 U	10	0.41	ug/l	1	10/31/11	11/01/11	BL	SW846 6010C [1]	SW846 3010A [4]
Potassium	16 U	10000	16	ug/l	1	10/31/11	11/01/11	BL	SW846 6010C [1]	SW846 3010A [4]
Selenium	1.5 U	10	1.5	ug/l	1	10/31/11	11/01/11	BL	SW846 6010C [1]	SW846 3010A [4]
Silver	0.72 U	10	0.72	ug/l	1	10/31/11	11/01/11	BL	SW846 6010C [1]	SW846 3010A [4]
Sodium	22.5 B	10000	14	ug/l	1	10/31/11	11/01/11	BL	SW846 6010C [1]	SW846 3010A [4]
Thallium	0.17 U	2.0	0.17	ug/l	1	10/31/11	11/01/11	BL	SW846 6010C [1]	SW846 3010A [4]
Vanadium	0.43 U	50	0.43	ug/l	1	10/31/11	11/01/11	BL	SW846 6010C [1]	SW846 3010A [4]
Zinc	4.2 B	20	1.7	ug/l	1	10/31/11	11/01/11	BL	SW846 6010C [1]	SW846 3010A [4]

(1) Instrument QC Batch: MA27368
(2) Instrument QC Batch: MA27369
(3) Instrument QC Batch: MA27404
(4) Prep QC Batch: MP61019
(5) Prep QC Batch: MP61019A
(6) Prep QC Batch: MP61173

RL = Reporting Limit
MDL = Method Detection Limit
U = Indicates a result < MDL
B = Indicates a result > = MDL but < RL

Report of Analysis

Client Sample ID:	PMPAIRSHAFT-SED-102011		
Lab Sample ID:	JA89742-2	**Date Sampled:**	10/20/11
Matrix:	SO - Soil	**Date Received:**	10/20/11
Method:	SW846 8260B SW846 5035	**Percent Solids:**	32.1
Project:	Ringwood, NJ		

	File ID	DF	Analyzed	By	Prep Date	Prep Batch	Analytical Batch
Run #1	G143272.D	1	11/03/11	SJM	10/21/11 09:00	n/a	VG6694
Run #2							

	Initial Weight
Run #1	3.5 g
Run #2	

VOA TCL List (OLM4.2)

CAS No.	Compound	Result	RL	MDL	Units	Q
67-64-1	Acetone	0.121	0.045	0.029	mg/kg	
71-43-2	Benzene	0.0463	0.0045	0.00059	mg/kg	
75-27-4	Bromodichloromethane	ND	0.022	0.0010	mg/kg	
75-25-2	Bromoform	ND	0.022	0.0034	mg/kg	
74-83-9	Bromomethane	ND	0.022	0.0018	mg/kg	
78-93-3	2-Butanone (MEK)	ND	0.045	0.019	mg/kg	
75-15-0	Carbon disulfide	ND	0.022	0.00087	mg/kg	
56-23-5	Carbon tetrachloride	ND	0.022	0.0015	mg/kg	
108-90-7	Chlorobenzene	0.0692	0.022	0.0014	mg/kg	
75-00-3	Chloroethane	ND	0.022	0.0018	mg/kg	
67-66-3	Chloroform	ND	0.022	0.0021	mg/kg	
74-87-3	Chloromethane	ND	0.022	0.0028	mg/kg	
110-82-7	Cyclohexane	0.0336	0.022	0.0017	mg/kg	
96-12-8	1,2-Dibromo-3-chloropropane	ND	0.045	0.0067	mg/kg	
124-48-1	Dibromochloromethane	ND	0.022	0.00075	mg/kg	
106-93-4	1,2-Dibromoethane	ND	0.0045	0.0011	mg/kg	
95-50-1	1,2-Dichlorobenzene	0.0096	0.022	0.0012	mg/kg	J
541-73-1	1,3-Dichlorobenzene	0.0267	0.022	0.00085	mg/kg	
106-46-7	1,4-Dichlorobenzene	0.0785	0.022	0.00076	mg/kg	
75-71-8	Dichlorodifluoromethane	ND	0.022	0.0014	mg/kg	
75-34-3	1,1-Dichloroethane	ND	0.022	0.00097	mg/kg	
107-06-2	1,2-Dichloroethane	ND	0.0045	0.00081	mg/kg	
75-35-4	1,1-Dichloroethene	ND	0.022	0.0027	mg/kg	
156-59-2	cis-1,2-Dichloroethene	ND	0.022	0.0014	mg/kg	
156-60-5	trans-1,2-Dichloroethene	ND	0.022	0.0019	mg/kg	
78-87-5	1,2-Dichloropropane	ND	0.022	0.0012	mg/kg	
10061-01-5	cis-1,3-Dichloropropene	ND	0.022	0.00068	mg/kg	
10061-02-6	trans-1,3-Dichloropropene	ND	0.022	0.0015	mg/kg	
100-41-4	Ethylbenzene	ND	0.0045	0.00066	mg/kg	
76-13-1	Freon 113	ND	0.022	0.0032	mg/kg	
591-78-6	2-Hexanone	ND	0.022	0.011	mg/kg	
98-82-8	Isopropylbenzene	0.207	0.022	0.00061	mg/kg	

ND = Not detected
MDL - Method Detection Limit
J = Indicates an estimated value
RL = Reporting Limit
B = Indicates analyte found in associated method blank
E = Indicates value exceeds calibration range
N = Indicates presumptive evidence of a compound

Report of Analysis

Client Sample ID:	PMPAIRSHAFT-SED-102011		
Lab Sample ID:	JA89742-2	**Date Sampled:**	10/20/11
Matrix:	SO - Soil	**Date Received:**	10/20/11
Method:	SW846 8260B SW846 5035	**Percent Solids:**	32.1
Project:	Ringwood, NJ		

VOA TCL List (OLM4.2)

CAS No.	Compound	Result	RL	MDL	Units	Q
79-20-9	Methyl Acetate	ND	0.022	0.0099	mg/kg	
108-87-2	Methylcyclohexane	0.0356	0.022	0.0011	mg/kg	
1634-04-4	Methyl Tert Butyl Ether	ND	0.0045	0.00080	mg/kg	
108-10-1	4-Methyl-2-pentanone(MIBK)	ND	0.022	0.012	mg/kg	
75-09-2	Methylene chloride	ND	0.022	0.0010	mg/kg	
100-42-5	Styrene	ND	0.022	0.00082	mg/kg	
79-34-5	1,1,2,2-Tetrachloroethane	ND	0.022	0.00080	mg/kg	
127-18-4	Tetrachloroethene	ND	0.022	0.00085	mg/kg	
108-88-3	Toluene	ND	0.0045	0.0017	mg/kg	
120-82-1	1,2,4-Trichlorobenzene	0.0041	0.022	0.0015	mg/kg	J
71-55-6	1,1,1-Trichloroethane	ND	0.022	0.0011	mg/kg	
79-00-5	1,1,2-Trichloroethane	ND	0.022	0.0019	mg/kg	
79-01-6	Trichloroethene	ND	0.022	0.0011	mg/kg	
75-69-4	Trichlorofluoromethane	ND	0.022	0.0021	mg/kg	
75-01-4	Vinyl chloride	ND	0.022	0.0021	mg/kg	
1330-20-7	Xylene (total)	0.209	0.0045	0.00082	mg/kg	

CAS No.	Surrogate Recoveries	Run# 1	Run# 2	Limits
1868-53-7	Dibromofluoromethane	96%		67-131%
17060-07-0	1,2-Dichloroethane-D4	87%		66-130%
2037-26-5	Toluene-D8	100%		76-125%
460-00-4	4-Bromofluorobenzene	103%		53-142%

CAS No.	Tentatively Identified Compounds	R.T.	Est. Conc.	Units	Q
	cycloalkane/alkene	9.45	.044	mg/kg	J
	C3 alkyl benzene	21.66	.037	mg/kg	J
	1,2,4-Trimethylbenzene	21.91	.1	mg/kg	J
496-11-7	Indan	23.36	.04	mg/kg	JN
	C4 alkyl benzene	23.74	.055	mg/kg	J
	C4 alkyl benzene	23.90	.075	mg/kg	J
	C4 alkyl benzene	24.56	.079	mg/kg	J
	C4 alkyl benzene	24.69	.11	mg/kg	J
	C4 alkyl benzene	25.42	.053	mg/kg	J
	unknown	25.58	.042	mg/kg	J
	Total TIC, Volatile		.635	mg/kg	J

ND = Not detected MDL - Method Detection Limit J = Indicates an estimated value
RL = Reporting Limit B = Indicates analyte found in associated method blank
E = Indicates value exceeds calibration range N = Indicates presumptive evidence of a compound

Report of Analysis

Client Sample ID: PMPAIRSHAFT-SED-102011
Lab Sample ID: JA89742-2 **Date Sampled:** 10/20/11
Matrix: SO - Soil **Date Received:** 10/20/11
Method: SW846 8270D SW846 3550C **Percent Solids:** 32.1
Project: Ringwood, NJ

	File ID	DF	Analyzed	By	Prep Date	Prep Batch	Analytical Batch
Run #1	F10304.D	1	11/07/11	NAP	10/28/11	OP52738	EF4664
Run #2							

	Initial Weight	Final Volume
Run #1	20.0 g	1.0 ml
Run #2		

ABN TCL List

CAS No.	Compound	Result	RL	MDL	Units	Q
95-57-8	2-Chlorophenol	ND	0.78	0.16	mg/kg	
59-50-7	4-Chloro-3-methyl phenol	ND	0.78	0.16	mg/kg	
120-83-2	2,4-Dichlorophenol	ND	0.78	0.25	mg/kg	
105-67-9	2,4-Dimethylphenol	ND	0.78	0.26	mg/kg	
51-28-5	2,4-Dinitrophenol	ND	3.1	0.19	mg/kg	
534-52-1	4,6-Dinitro-o-cresol	ND	3.1	0.19	mg/kg	
95-48-7	2-Methylphenol	ND	0.31	0.18	mg/kg	
	3&4-Methylphenol	ND	0.31	0.20	mg/kg	
88-75-5	2-Nitrophenol	ND	0.78	0.17	mg/kg	
100-02-7	4-Nitrophenol	ND	1.6	0.26	mg/kg	
108-95-2	Phenol	ND	0.31	0.16	mg/kg	
95-95-4	2,4,5-Trichlorophenol	ND	0.78	0.18	mg/kg	
88-06-2	2,4,6-Trichlorophenol	ND	0.78	0.15	mg/kg	
98-86-2	Acetophenone	ND	0.78	0.027	mg/kg	
1912-24-9	Atrazine	ND	0.78	0.031	mg/kg	
101-55-3	4-Bromophenyl phenyl ether	ND	0.31	0.057	mg/kg	
85-68-7	Butyl benzyl phthalate	ND	0.31	0.090	mg/kg	
92-52-4	1,1'-Biphenyl	ND	0.31	0.018	mg/kg	
100-52-7	Benzaldehyde	ND	0.78	0.036	mg/kg	
91-58-7	2-Chloronaphthalene	ND	0.31	0.048	mg/kg	
106-47-8	4-Chloroaniline	ND	0.78	0.050	mg/kg	
86-74-8	Carbazole	ND	0.31	0.072	mg/kg	
105-60-2	Caprolactam	ND	0.31	0.049	mg/kg	
111-91-1	bis(2-Chloroethoxy)methane	ND	0.31	0.063	mg/kg	
111-44-4	bis(2-Chloroethyl)ether	ND	0.31	0.047	mg/kg	
108-60-1	bis(2-Chloroisopropyl)ether	ND	0.31	0.046	mg/kg	
7005-72-3	4-Chlorophenyl phenyl ether	ND	0.31	0.047	mg/kg	
121-14-2	2,4-Dinitrotoluene	ND	0.31	0.068	mg/kg	
606-20-2	2,6-Dinitrotoluene	ND	0.31	0.059	mg/kg	
91-94-1	3,3'-Dichlorobenzidine	ND	0.78	0.040	mg/kg	
132-64-9	Dibenzofuran	ND	0.31	0.046	mg/kg	
84-74-2	Di-n-butyl phthalate	ND	0.31	0.035	mg/kg	

ND = Not detected MDL - Method Detection Limit
RL = Reporting Limit
E = Indicates value exceeds calibration range
J = Indicates an estimated value
B = Indicates analyte found in associated method blank
N = Indicates presumptive evidence of a compound

Report of Analysis

Client Sample ID:	PMPAIRSHAFT-SED-102011		
Lab Sample ID:	JA89742-2	**Date Sampled:**	10/20/11
Matrix:	SO - Soil	**Date Received:**	10/20/11
Method:	SW846 8270D SW846 3550C	**Percent Solids:**	32.1
Project:	Ringwood, NJ		

ABN TCL List

CAS No.	Compound	Result	RL	MDL	Units	Q
117-84-0	Di-n-octyl phthalate	ND	0.31	0.076	mg/kg	
84-66-2	Diethyl phthalate	ND	0.31	0.053	mg/kg	
131-11-3	Dimethyl phthalate	0.250	0.31	0.055	mg/kg	J
117-81-7	bis(2-Ethylhexyl)phthalate	1.21	0.31	0.14	mg/kg	
87-68-3	Hexachlorobutadiene	ND	0.16	0.043	mg/kg	
77-47-4	Hexachlorocyclopentadiene	ND	3.1	0.16	mg/kg	
67-72-1	Hexachloroethane	ND	0.78	0.043	mg/kg	
78-59-1	Isophorone	ND	0.31	0.042	mg/kg	
91-57-6	2-Methylnaphthalene	0.127	0.31	0.087	mg/kg	J
88-74-4	2-Nitroaniline	ND	0.78	0.069	mg/kg	
99-09-2	3-Nitroaniline	ND	0.78	0.062	mg/kg	
100-01-6	4-Nitroaniline	ND	0.78	0.061	mg/kg	
98-95-3	Nitrobenzene	ND	0.31	0.045	mg/kg	
621-64-7	N-Nitroso-di-n-propylamine	ND	0.31	0.038	mg/kg	
86-30-6	N-Nitrosodiphenylamine	0.165	0.78	0.093	mg/kg	J

CAS No.	Surrogate Recoveries	Run# 1	Run# 2	Limits
367-12-4	2-Fluorophenol	57%		21-116%
4165-62-2	Phenol-d5	57%		19-117%
118-79-6	2,4,6-Tribromophenol	100%		24-136%
4165-60-0	Nitrobenzene-d5	70%		21-122%
321-60-8	2-Fluorobiphenyl	77%		30-117%
1718-51-0	Terphenyl-d14	96%		31-129%

CAS No.	Tentatively Identified Compounds	R.T.	Est. Conc.	Units	Q
	system artifact	1.49	1	mg/kg	J
	system artifact/aldol-condensation	2.68	45	mg/kg	J
	unknown	13.28	3	mg/kg	J
	unknown	13.52	2.9	mg/kg	J
	unknown	14.06	1.1	mg/kg	J
	alkane	14.43	2.9	mg/kg	J
	alkane	15.06	1.8	mg/kg	J
	unknown	15.08	5.2	mg/kg	J
	unknown	15.48	.94	mg/kg	J
	alkane	15.66	3.9	mg/kg	J
	unknown	15.70	2.4	mg/kg	J
	unknown	16.13	1.4	mg/kg	J
	unknown	16.23	2	mg/kg	J

ND = Not detected MDL - Method Detection Limit J = Indicates an estimated value
RL = Reporting Limit B = Indicates analyte found in associated method blank
E = Indicates value exceeds calibration range N = Indicates presumptive evidence of a compound

Report of Analysis

Client Sample ID:	PMPAIRSHAFT-SED-102011		
Lab Sample ID:	JA89742-2	**Date Sampled:**	10/20/11
Matrix:	SO - Soil	**Date Received:**	10/20/11
Method:	SW846 8270D SW846 3550C	**Percent Solids:**	32.1
Project:	Ringwood, NJ		

ABN TCL List

CAS No.	Tentatively Identified Compounds	R.T.	Est. Conc.	Units	Q
	alkane	16.31	2.5	mg/kg	J
	unknown	16.42	2.5	mg/kg	J
10191-41-0	Vitamin e	16.52	7	mg/kg	JN
	unknown	16.91	1.2	mg/kg	J
	unknown	17.25	3.9	mg/kg	J
	unknown	17.53	21	mg/kg	J
	unknown	17.65	9.6	mg/kg	J
	unknown	17.80	2.3	mg/kg	J
	unknown	17.85	6.6	mg/kg	J
	unknown	17.91	8.2	mg/kg	J
	unknown	18.03	4.5	mg/kg	J
	unknown	18.15	6.2	mg/kg	J
	unknown	18.27	8.3	mg/kg	J
	Total TIC, Semi-Volatile		111.34	mg/kg	J

ND = Not detected MDL - Method Detection Limit
RL = Reporting Limit
E = Indicates value exceeds calibration range
J = Indicates an estimated value
B = Indicates analyte found in associated method blank
N = Indicates presumptive evidence of a compound

Report of Analysis

Client Sample ID:	PMPAIRSHAFT-SED-102011		
Lab Sample ID:	JA89742-2	**Date Sampled:**	10/20/11
Matrix:	SO - Soil	**Date Received:**	10/20/11
Method:	SW846 8270D BY SIM SW846 3550C	**Percent Solids:**	32.1
Project:	Ringwood, NJ		

	File ID	DF	Analyzed	By	Prep Date	Prep Batch	Analytical Batch
Run #1	4M29623.D	1	11/11/11	NAP	10/28/11	OP52738A	E4M1259
Run #2							

	Initial Weight	Final Volume
Run #1	20.0 g	1.0 ml
Run #2		

CAS No.	Compound	Result	RL	MDL	Units	Q
87-86-5	Pentachlorophenol	ND	0.078	0.051	mg/kg	
83-32-9	Acenaphthene	0.0592	0.016	0.0022	mg/kg	
208-96-8	Acenaphthylene	ND	0.016	0.0019	mg/kg	
120-12-7	Anthracene	0.0384	0.016	0.0019	mg/kg	
56-55-3	Benzo(a)anthracene	0.105	0.016	0.0052	mg/kg	
50-32-8	Benzo(a)pyrene	0.109	0.016	0.0027	mg/kg	
205-99-2	Benzo(b)fluoranthene	0.144	0.016	0.0024	mg/kg	
191-24-2	Benzo(g,h,i)perylene	0.0889	0.016	0.0023	mg/kg	
207-08-9	Benzo(k)fluoranthene	0.122	0.016	0.0025	mg/kg	
218-01-9	Chrysene	0.115	0.016	0.0027	mg/kg	
53-70-3	Dibenzo(a,h)anthracene	0.0402	0.016	0.0037	mg/kg	
206-44-0	Fluoranthene	0.182	0.016	0.0016	mg/kg	
86-73-7	Fluorene	0.0650	0.016	0.0015	mg/kg	
118-74-1	Hexachlorobenzene	ND	0.016	0.0016	mg/kg	
193-39-5	Indeno(1,2,3-cd)pyrene	0.0886	0.016	0.0026	mg/kg	
91-20-3	Naphthalene	0.345	0.016	0.0018	mg/kg	
85-01-8	Phenanthrene	0.168	0.016	0.0018	mg/kg	
129-00-0	Pyrene	0.188	0.016	0.0014	mg/kg	

CAS No.	Surrogate Recoveries	Run# 1	Run# 2	Limits
367-12-4	2-Fluorophenol	60%		21-124%
4165-62-2	Phenol-d5	58%		19-119%
118-79-6	2,4,6-Tribromophenol	73%		20-136%
4165-60-0	Nitrobenzene-d5	60%		18-123%
321-60-8	2-Fluorobiphenyl	60%		24-113%
1718-51-0	Terphenyl-d14	69%		21-126%

ND = Not detected   MDL - Method Detection Limit   J = Indicates an estimated value
RL = Reporting Limit   B = Indicates analyte found in associated method blank
E = Indicates value exceeds calibration range   N = Indicates presumptive evidence of a compound

Report of Analysis

Client Sample ID:	PMPAIRSHAFT-SED-102011		
Lab Sample ID:	JA89742-2	**Date Sampled:**	10/20/11
Matrix:	SO - Soil	**Date Received:**	10/20/11
Method:	SW846 8082A SW846 3545A	**Percent Solids:**	32.1
Project:	Ringwood, NJ		

	File ID	DF	Analyzed	By	Prep Date	Prep Batch	Analytical Batch
Run #1 [a]	2G60657.D	1	11/15/11	AZ	11/15/11	OP53090	G2G2221
Run #2							

	Initial Weight	Final Volume
Run #1	10.0 g	1.0 ml
Run #2		

PCB List

CAS No.	Compound	Result	RL	MDL	Units	Q
12674-11-2	Aroclor 1016	ND	0.016	0.0040	mg/kg	
11104-28-2	Aroclor 1221	ND	0.016	0.0094	mg/kg	
11141-16-5	Aroclor 1232	ND	0.016	0.0079	mg/kg	
53469-21-9	Aroclor 1242	ND	0.016	0.0050	mg/kg	
12672-29-6	Aroclor 1248	ND	0.016	0.0047	mg/kg	
11097-69-1	Aroclor 1254	ND	0.016	0.0073	mg/kg	
11096-82-5	Aroclor 1260	ND	0.016	0.0051	mg/kg	

CAS No.	Surrogate Recoveries	Run# 1	Run# 2	Limits
877-09-8	Tetrachloro-m-xylene	67%		22-141%
877-09-8	Tetrachloro-m-xylene	77%		22-141%
2051-24-3	Decachlorobiphenyl	74%		18-163%
2051-24-3	Decachlorobiphenyl	90%		18-163%

(a) Re-extracted due to lab contaminated on original extract. originally prep date was within holding time.

ND = Not detected MDL - Method Detection Limit J = Indicates an estimated value
RL = Reporting Limit B = Indicates analyte found in associated method blank
E = Indicates value exceeds calibration range N = Indicates presumptive evidence of a compound

Report of Analysis

Client Sample ID: PMPAIRSHAFT-SED-102011
Lab Sample ID: JA89742-2
Matrix: SO - Soil
Date Sampled: 10/20/11
Date Received: 10/20/11
Percent Solids: 32.1
Project: Ringwood, NJ

Metals Analysis

Analyte	Result	RL	MDL	Units	DF	Prep	Analyzed	By	Method	Prep Method
Aluminum [a]	14800	100	4.3	mg/kg	2	11/10/11	11/11/11	ND	SW846 6010C [4]	SW846 3050B [5]
Antimony	0.77 B	2.0	0.12	mg/kg	1	11/09/11	11/10/11	VC	SW846 6010C [2]	SW846 3050B [5]
Arsenic	10.6	0.25	0.029	mg/kg	5	11/09/11	11/09/11	RP	SW846 6020A [3]	SW846 3050B [6]
Barium	165	20	0.13	mg/kg	1	11/09/11	11/10/11	VC	SW846 6010C [2]	SW846 3050B [5]
Beryllium	0.84	0.20	0.015	mg/kg	1	11/09/11	11/10/11	VC	SW846 6010C [2]	SW846 3050B [5]
Cadmium	1.0	0.49	0.034	mg/kg	1	11/09/11	11/10/11	VC	SW846 6010C [2]	SW846 3050B [5]
Calcium [a]	6450	1000	10	mg/kg	2	11/10/11	11/11/11	ND	SW846 6010C [4]	SW846 3050B [5]
Chromium	23.1	2.0	0.061	mg/kg	1	11/09/11	11/10/11	VC	SW846 6010C [2]	SW846 3050B [5]
Cobalt	6.2	4.9	0.031	mg/kg	1	11/09/11	11/10/11	VC	SW846 6010C [2]	SW846 3050B [5]
Copper	42.2	2.5	0.11	mg/kg	1	11/09/11	11/10/11	VC	SW846 6010C [2]	SW846 3050B [5]
Iron [a]	34100	100	4.7	mg/kg	2	11/10/11	11/11/11	ND	SW846 6010C [4]	SW846 3050B [5]
Lead	64.8	2.0	0.11	mg/kg	1	11/09/11	11/10/11	VC	SW846 6010C [2]	SW846 3050B [5]
Magnesium [a]	3250	1000	2.7	mg/kg	2	11/10/11	11/11/11	ND	SW846 6010C [4]	SW846 3050B [5]
Manganese	244	1.5	0.031	mg/kg	1	11/09/11	11/10/11	VC	SW846 6010C [2]	SW846 3050B [5]
Mercury	0.57	0.10	0.039	mg/kg	1	11/09/11	11/09/11	MP	SW846 7471B [1]	SW846 7471B [7]
Nickel	24.2	3.9	0.064	mg/kg	1	11/09/11	11/10/11	VC	SW846 6010C [2]	SW846 3050B [5]
Potassium [a]	1230 B	2000	6.3	mg/kg	2	11/10/11	11/11/11	ND	SW846 6010C [4]	SW846 3050B [5]
Selenium	0.26 U	2.0	0.26	mg/kg	1	11/09/11	11/10/11	VC	SW846 6010C [2]	SW846 3050B [5]
Silver	0.068 U	0.49	0.068	mg/kg	1	11/09/11	11/10/11	VC	SW846 6010C [2]	SW846 3050B [5]
Sodium [a]	101 B	2000	50	mg/kg	2	11/10/11	11/11/11	ND	SW846 6010C [4]	SW846 3050B [5]
Thallium	0.21 U	0.99	0.21	mg/kg	1	11/09/11	11/10/11	VC	SW846 6010C [2]	SW846 3050B [5]
Vanadium	55.8	4.9	0.063	mg/kg	1	11/09/11	11/10/11	VC	SW846 6010C [2]	SW846 3050B [5]
Zinc	148	2.0	0.47	mg/kg	1	11/09/11	11/10/11	VC	SW846 6010C [2]	SW846 3050B [5]

(1) Instrument QC Batch: MA27407
(2) Instrument QC Batch: MA27410
(3) Instrument QC Batch: MA27414
(4) Instrument QC Batch: MA27424
(5) Prep QC Batch: MP61185
(6) Prep QC Batch: MP61185A
(7) Prep QC Batch: MP61187

(a) Elevated detection limit due to dilution required for matrix interference (indicated by failing internal standard on original analysis).

RL = Reporting Limit
MDL = Method Detection Limit
U = Indicates a result < MDL
B = Indicates a result > = MDL but < RL

Report of Analysis

Client Sample ID:	TB102011		
Lab Sample ID:	JA89742-3	**Date Sampled:**	10/20/11
Matrix:	AQ - Trip Blank Soil	**Date Received:**	10/20/11
Method:	SW846 8260B	**Percent Solids:**	n/a
Project:	Ringwood, NJ		

	File ID	DF	Analyzed	By	Prep Date	Prep Batch	Analytical Batch
Run #1	2C88298.D	1	10/25/11	DR	n/a	n/a	V2C4029
Run #2							

	Purge Volume
Run #1	5.0 ml
Run #2	

VOA TCL List (OLM4.2)

CAS No.	Compound	Result	RL	MDL	Units	Q
67-64-1	Acetone	ND	10	7.6	ug/l	
71-43-2	Benzene	ND	1.0	0.22	ug/l	
75-27-4	Bromodichloromethane	ND	1.0	0.23	ug/l	
75-25-2	Bromoform	ND	4.0	0.24	ug/l	
74-83-9	Bromomethane	ND	2.0	0.31	ug/l	
78-93-3	2-Butanone (MEK)	ND	10	2.9	ug/l	
75-15-0	Carbon disulfide	ND	2.0	0.18	ug/l	
56-23-5	Carbon tetrachloride	ND	1.0	0.19	ug/l	
108-90-7	Chlorobenzene	ND	1.0	0.22	ug/l	
75-00-3	Chloroethane	ND	1.0	0.37	ug/l	
67-66-3	Chloroform	ND	1.0	0.21	ug/l	
74-87-3	Chloromethane	ND	1.0	0.22	ug/l	
110-82-7	Cyclohexane	ND	5.0	0.29	ug/l	
96-12-8	1,2-Dibromo-3-chloropropane	ND	10	1.3	ug/l	
124-48-1	Dibromochloromethane	ND	1.0	0.20	ug/l	
106-93-4	1,2-Dibromoethane	ND	2.0	0.21	ug/l	
95-50-1	1,2-Dichlorobenzene	ND	1.0	0.18	ug/l	
541-73-1	1,3-Dichlorobenzene	ND	1.0	0.29	ug/l	
106-46-7	1,4-Dichlorobenzene	ND	1.0	0.26	ug/l	
75-71-8	Dichlorodifluoromethane	ND	5.0	0.31	ug/l	
75-34-3	1,1-Dichloroethane	ND	1.0	0.19	ug/l	
107-06-2	1,2-Dichloroethane	ND	1.0	0.18	ug/l	
75-35-4	1,1-Dichloroethene	ND	1.0	0.28	ug/l	
156-59-2	cis-1,2-Dichloroethene	ND	1.0	0.22	ug/l	
156-60-5	trans-1,2-Dichloroethene	ND	1.0	0.31	ug/l	
78-87-5	1,2-Dichloropropane	ND	1.0	0.22	ug/l	
10061-01-5	cis-1,3-Dichloropropene	ND	1.0	0.22	ug/l	
10061-02-6	trans-1,3-Dichloropropene	ND	1.0	0.19	ug/l	
100-41-4	Ethylbenzene	ND	1.0	0.21	ug/l	
76-13-1	Freon 113	ND	5.0	0.49	ug/l	
591-78-6	2-Hexanone	ND	5.0	3.0	ug/l	
98-82-8	Isopropylbenzene	ND	2.0	0.19	ug/l	

ND = Not detected MDL - Method Detection Limit J = Indicates an estimated value
RL = Reporting Limit B = Indicates analyte found in associated method blank
E = Indicates value exceeds calibration range N = Indicates presumptive evidence of a compound

Report of Analysis

Client Sample ID:	TB102011		
Lab Sample ID:	JA89742-3	**Date Sampled:**	10/20/11
Matrix:	AQ - Trip Blank Soil	**Date Received:**	10/20/11
Method:	SW846 8260B	**Percent Solids:**	n/a
Project:	Ringwood, NJ		

VOA TCL List (OLM4.2)

CAS No.	Compound	Result	RL	MDL	Units	Q
79-20-9	Methyl Acetate	ND	5.0	2.9	ug/l	
108-87-2	Methylcyclohexane	ND	5.0	0.18	ug/l	
1634-04-4	Methyl Tert Butyl Ether	ND	1.0	0.18	ug/l	
108-10-1	4-Methyl-2-pentanone(MIBK)	ND	5.0	1.2	ug/l	
75-09-2	Methylene chloride	ND	2.0	0.20	ug/l	
100-42-5	Styrene	ND	5.0	0.23	ug/l	
79-34-5	1,1,2,2-Tetrachloroethane	ND	1.0	0.20	ug/l	
127-18-4	Tetrachloroethene	ND	1.0	0.32	ug/l	
108-88-3	Toluene	ND	1.0	0.15	ug/l	
120-82-1	1,2,4-Trichlorobenzene	ND	5.0	0.15	ug/l	
71-55-6	1,1,1-Trichloroethane	ND	1.0	0.24	ug/l	
79-00-5	1,1,2-Trichloroethane	ND	1.0	0.23	ug/l	
79-01-6	Trichloroethene	ND	1.0	0.21	ug/l	
75-69-4	Trichlorofluoromethane	ND	5.0	0.35	ug/l	
75-01-4	Vinyl chloride	ND	1.0	0.27	ug/l	
1330-20-7	Xylene (total)	ND	1.0	0.17	ug/l	

CAS No.	Surrogate Recoveries	Run# 1	Run# 2	Limits
1868-53-7	Dibromofluoromethane	99%		77-120%
17060-07-0	1,2-Dichloroethane-D4	88%		70-127%
2037-26-5	Toluene-D8	99%		79-120%
460-00-4	4-Bromofluorobenzene	93%		76-118%

CAS No.	Tentatively Identified Compounds	R.T.	Est. Conc.	Units	Q
	Total TIC, Volatile		0	ug/l	

ND = Not detected MDL - Method Detection Limit J = Indicates an estimated value
RL = Reporting Limit B = Indicates analyte found in associated method blank
E = Indicates value exceeds calibration range N = Indicates presumptive evidence of a compound

New Jersey
ACCUTEST
LABORATORIES

4

Misc. Forms

Custody Documents and Other Forms

Includes the following where applicable:

- Chain of Custody

ACCUTEST LABORATORIES SLL ER SB

CHAIN OF CUSTODY

2235 Route 130, Dayton, NJ 08810
Tel: 732-329-0200 FAX: 732-329-3499/3480
www. acutest.com

FED-EX Tracking #	Bottle Order Control #
Accutest Quote #	Accutest Job # JA89742

Client / Reporting Information

Company Name: ARCADIS
Street Address: 17-17 Rt 208 NORTH
City: FAIR LAWN State: NJ Zip:
Project Contact: ERICH ZIMMERMAN E-mail:
Phone #: 201-398-4364 Fax #:
Sampler(s) Name(s): J. ROCKLIN / J. SEIER Phone #:

Project Information

Project Name: RINGWOOD MINES/LANDFILL SITE
Street:
City: State:
Project #: NJ000604.0035
Client Purchase Order #:
Project Manager: ERICH ZIMMERMAN

Billing Information (if different from Report to)
Company Name:
Street Address:
City: State: Zip:
Attention:

Requested Analysis (see TEST CODE sheet): VOC (TCL) ORGANICS; METALS (TAL); PCB's; SVOCS

Accutest Sample #	Field ID / Point of Collection	MEOH/DI Vial #	Date	Time	Sampled by	Matrix	# of bottles	HCl	NaOH	HNO3	H2SO4	NONE	DI Water	MEOH	ENCORE	VOC (TCL) ORGANICS	METALS (TAL)	PCB's	SVOCS	LAB USE ONLY
-1	PMPAIRSHAFT-FB-102011		10-20-11	1200	JR/JS	FB	8	2	1	1		4				X	X	X	X	
-2	PMPAIRSHAFT-SED-102011		10-20-11	15:00	JR/JS	SED	5					1			4	X	X	X	X	EX23
-3	TB102011		10/18/11	1700	—	TB	2	2								X				AMET 10
																				UC31
																				971
																				UTC 38
																				14C2
																				4035

Matrix Codes

DW - Drinking Water
GW - Ground Water
WW - Water
SW - Surface Water
SO - Soil
SL - Sludge
SED-Sediment
OI - Oil
LIQ - Other Liquid
AIR - Air
SOL - Other Solid
WP - Wipe
FB-Field Blank
EB-Equipment Blank
RB- Rinse Blank
TB-Trip Blank

Turnaround Time (Business days)

- [x] Std. 15 Business Days
- [ ] Std. 10 Business Days (by Contract only)
- [ ] 10 Day RUSH
- [ ] 5 Day RUSH
- [ ] 3 Day EMERGENCY
- [ ] 2 Day EMERGENCY
- [ ] 1 Day EMERGENCY

Emergency & Rush T/A data available VIA Lablink

Approved By (Accutest PM): / Date:

Data Deliverable Information

- [ ] Commercial "A" (Level 1)
- [ ] Commercial "B" (Level 2)
- [ ] FULLT1 (Level 3+4)
- [ ] NJ Reduced
- [ ] Commercial "C"
- [ ] NYASP Category A
- [ ] NYASP Category B
- [ ] State Forms
- [ ] EDD Format ______
- [ ] Other ______

Commercial "A" = Results Only
Commercial "B" = Results + QC Summary
NJ Reduced = Results + QC Summary + Partial Raw data

Comments / Special Instructions

4 encores 10/21/11

Sample Custody must be documented below each time samples change possession, including courier delivery.

Relinquished by Sampler: 1 JR	Date Time: 10/20/11 1535	Received By: 1 John Pepe	10/20/11 1535	Relinquished By: 2 John Pempo	Date Time: 10/21/11 1710	Received By: 2
Relinquished by Sampler: 3	Date Time:	Received By: 3	Relinquished By: 4	Date Time:	Received By: 4
Relinquished by: 5	Date Time:	Received By: 5	Custody Seal # No	☐ Intact ☐ Not intact	Preserved where applicable: ☐ On Ice	Cooler Temp. 1.0°C

B 1 Cooler B GP

JA89742: Chain of Custody
Page 1 of 3

ACCUTEST LABORATORIES

Accutest Laboratories Sample Receipt Summary

Accutest Job Number: JA89742 **Client:** ARCADIS **Immediate Client Services Action Required:** No

Date / Time Received: 10/20/2011 17:40 **Delivery Method:** Accutest Courier **Client Service Action Required at Login:** Yes

Project: RINGWOOD LANDFILL **No. Coolers:** **Airbill #'s:**

Cooler Security

	Y	N
1. Custody Seals Present:	☐	☑
2. Custody Seals Intact:	☐	☑
3. COC Present:	☑	☐
4. Smpl Dates/Time OK	☐	☑

Cooler Temperature

	Y	N
1. Temp criteria achieved:	☑	☐
2. Cooler temp verification:	IR Gun	
3. Cooler media:	Ice (bag)	

Quality Control_Preservation

	Y	N	N/A
1. Trip Blank present / cooler:	☑	☐	☐
2. Trip Blank listed on COC:	☑	☐	☐
3. Samples preserved properly:	☑	☐	
4. VOCs headspace free:	☑	☐	☐

Sample Integrity - Documentation

	Y	N
1. Sample labels present on bottles:	☑	☐
2. Container labeling complete:	☐	☑
3. Sample container label / COC agree:	☐	☑

Sample Integrity - Condition

	Y	N
1. Sample recvd within HT:	☑	☐
2. All containers accounted for:	☑	☐
3. Condition of sample:	Intact	

Sample Integrity - Instructions

	Y	N	N/A
1. Analysis requested is clear:	☑	☐	
2. Bottles received for unspecified tests	☐	☑	
3. Sufficient volume recvd for analysis:	☑	☐	
4. Compositing instructions clear:	☐	☐	☑
5. Filtering instructions clear:	☐	☐	☑

Comments

-1 4 OF 4 EXT BOTTLES LABELED "SED" , NOT "FB" -NO TIMES ON LABELS, DATE OK
VO, METAL, CN OK

-2 REC'D 4 ENCORES

Sample Receipt Summary - Problem Resolution

Accutest Job Number: JA89742

CSR: Marie Meidhof **Response Date:** 10/21/2011

Response: 1. The 4 EXT bottles should be "field blank".

2. One of the 4 Encores may be low weight. Please preserve 3 as low-level and 1 as medium-level.

ARCADIS U.S., Inc.
100 East Campus View Blvd
Columbus
Ohio 43235
Tel 614 764 2310
Fax 614 764 1270

MEMO

To:
Gary Gengel, Esq.- Latham & Watkins, LLC

Copies:
Glen Logan, Ford Motor Company
Brian Bussa, Ford Motor Company
Tim Green, Esq., Ford Motor Company
Paola Macchiaroli, Ph.D., ARCADIS SEC
Joe Quinnan, PE, PG, ARCADIS-Director, Site Investigation Services

From:
Eric M. Cherry, Principal Scientist, ARCADIS Environmental Forensics

Date:
May 23, 2013

ARCADIS Project No.:
NJ000605.2013 0003

Subject:
Forensic Evaluation of Metals, Polynuclear Aromatic Hydrocarbons and Volatile Organic Compounds
Ringwood Landfill and Mining Site, Ringwood, NJ

Objective

The purpose of this memo is to document the data sources, methods and findings of the forensic evaluation of data available for sediments in the Peters Mine (PM) Air Shaft and paint sludge at the Ringwood Mines/Landfill Site in Ringwood, New Jersey. The specific objectives were as follows:

1) Compare sediment sample results with paint sludge results to determine if the sludges could be reasonable sources for metals, polynuclear aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs) in the sediments.
2) Conduct a ratio analysis of metals to compare the composition of samples and identify predominant compositional characteristics.
3) Complete a mixing model evaluation of PAHs to evaluate the likely source(s) of PAHs in sediments.
4) Evaluate the distribution of VOCs and semivolatile organic compounds (SVOCs) in sediment and paint sludges to identify similarities and differences in relative proportions.
5) Provide a qualitative evaluation of the likelihood of the partitioning of benzene from paint sludge to groundwater in the mine.

As a result of the forensic analysis described below, multiple lines of evidence have demonstrated that the sediments and paint sludge are not related. There is no data that would suggest that the paint sludges have contributed to the concentration of PAHs, phthalates, metals, or VOCs in the sediment sample.

Data Reviewed

Analytical data were available for 34 samples of paint sludge or solids from the site, and a sample of sediment (PMPAIRSHAFT-SED). These samples were collected and analyzed between March 1987 and April 2006, with the sediment sample being collected in October 2011. Analytical parameters included VOCs, SVOCs (with PAHs being a subset of the SVOC list), total petroleum hydrocarbons (TPH) and polychlorinated biphenyls (PCBs). It is noted that the parameter groups and specific parameters (compounds or elements) analyzed for each sample varied considerably given the span of time during which these analyses were completed. As such, the data set used for the evaluation of PAHs, metals, and VOCs varies in this forensic evaluation. Table 1 provides a summary of samples included in the evaluation of metals, PAH/SVOCs, and VOCs.

Method of Evaluation

Several methods were utilized to address the objectives of this evaluation. One fundamental method is comparing relative proportions or ratios of compounds or elements. In regard to PAHs, SVOCs, and VOCs, calculating the relative proportion of various common compounds allows for a side-by-side comparison of the relative distribution of compounds in different samples, regardless of the total concentration (Yunker et al., 2012). Ratios of various metals to a common element, in this case zinc, allows for side-by-side comparisons and statistical analysis (Paudyn and Smith, 1993; Hobbs and Almrall, 2003; Deconinck et al., 2006; Thorbjornsen and Myers, 2007). Graphic plots of ratios and relative proportions are considered to be “fingerprints” of potential source materials that are then compared with the corresponding “signal” that is measured in the environmental media. When considering the potential impact of contaminants derived from complex mixtures, it is essential to maintain continuity of the different components in that mixture as they interact with native environmental media such as sediments or groundwater that have the same constituents in their own relative proportions. Furthermore, when considering sources of materials that are not typically considered to be naturally occurring constituents in geologic materials, such as PAHs that co-occur in predictable proportions in different source materials, it is essential to be able to account for the individual compounds in their relative proportions as they form a new mixture that is identified in the potentially impacted media. The methods employed in this evaluation are consistent with forensic investigations as reported in the peer-reviewed literature. The graphics that accompany this report are intended to illustrate the relationships of these complex mixtures in a manner that makes the interpretation easier and does not require understanding of the underlying mathematical and statistical methods employed herein.

PAHs

PAH profiles were calculated for sixteen samples with detected concentrations of one or more individual PAH compounds detected in a given sample. PAH profiles were calculated by normalizing the relative proportion of each individual PAH detected to the sum of all PAHs detected, which allows for a side-by-side comparison of the relative proportion of PAHs in a given sample. (Recall that while concentrations may vary when sludge is mixed with sediment, the ratio of PAHs will remain essentially the same in the new mixture, thus providing a unique fingerprint or discriminant.) The objective of this approach is to gain insight as to the nature of the source materials contributing to the overall distribution. In addition to calculating the PAH proportions of each sample, the relative distribution of ring structures was also calculated. Priority Pollutant PAHs (plus 2-methyl naphthalene) consist of two to six fused aromatic rings. In general, PAH mixtures dominated by 2-ring and 3-ring PAHs are derived from petroleum sources, whereas mixtures dominated by 4-, 5-, and 6-ring PAHs are derived from combustion sources. The evaluation of PAHs and SVOCs includes the relative proportions of PAHs by ring structures plus total phthalates, which were the dominant SVOC compounds detected.

A mixing model was also run using multiple regression techniques to determine possible combinations of source materials that could match the observed PAH spectrum in the sediment sample. A preliminary review was conducted to compare the PAH profile for the sediment sample against PAH profiles for known source materials. Based on the distribution of PAHs, it was determined that the observed profile was a mixture of two or more sources. Two end-members PAH source profiles were used as input to the model, which include ***creosote*** *(coal-tar)* (Brown et al., 2006) representing a 2- and 3-ring dominated PAH mixture, and ***urban dust*** (a reference source material) (NIST, 2001) that is representative of a combustion source dominated by 4-, 5- and 6-ring PAHs (which include pyrogenic PAHs related to exhaust from fuel-fired equipment like generators, or possible fire events). This model was used to calculate the relative contribution of individual PAH compounds from the source materials that would predict the PAH profile observed in the sediment sample.

Metals

A total of 23 samples were included in the metals evaluation. The relative distribution of metals was evaluated by comparing the relative proportions of eight metals in each sample. Up to 25 metals were analyzed in different samples, although the same metals were not analyzed in all samples. A final suite of eight metals (antimony, copper, lead, zinc, chromium, cadmium, nickel, and arsenic) were selected for inclusion in the evaluation of the paint sludge and sediment sample based on high relative concentration of these metals and high detection or reporting frequency for these metals. In addition to evaluating the relative proportions of metals, multivariate cluster analysis was conducted on 22 samples based on the ratios of metals normalized to the zinc concentration in each sample (one sample was excluded because zinc was not analyzed). Cluster analysis is a standard statistical technique to identify natural groupings of samples based on the similarity of characteristics. Although it is most commonly applied in genetics, it is also frequently used in geological and environmental assessments to group samples based on similarity. Zinc was selected as the normalizing element because it is common to both paints and to the natural geological materials found at the Site, such as soil and sediment. (Per investigations conducted to date, zinc concentrations in native soils and sediment range from 60 to 100 millograms per kilogram [mg/kg]).

VOCs

A total of 24 samples were included in the VOC evaluation. VOCs were evaluated by calculating the relative proportions of benzene, toluene, ethylbenzene, xylenes, naphthalene, and the sum of other detected VOCs. The evaluation was based comparison of the distribution of these VOCs in different samples, regardless of total VOC concentration to allow for a side-by-side comparison using stack-chart histograms displaying the distributions.

Findings

The following items summarize the evaluation of the analytical data and chromatogram for these samples:

1) The PAH profile for the sediment sample consists of a broad mixture of 2- through 6-ring PAHs. In contrast, the PAH profiles for the paint sludge samples are dominated by 2-ring PAHs with little or negligible contribution from 3-, 4-, 5-, or 6-ring PAHs. The PAH profiles are not remotely similar; therefore the sediment sample does not match paint sludge. PAH profiles are provided on Figure 1.

2) A multiple-regression mixing model was used to identify a plausible mixture of two potential source materials that would match the PAH profile observed in the sediment sample. PAH profiles from the literature were selected as end-members for the model, including a creosote (coal tar or related products commonly used in mining timbers) source, representing the low molecular weight PAHs, and an urban dust source (related to mine fires or exhaust from fuel-fired equipment), representing the higher molecular weight PAHs from combustion sources. The best-fit mixing model predicts a combination of 47% creosote and 53% combustion material. Input profiles, the sediment profile, predicted mixture profile and a comparison profile are provided on Figure 2.

3) Likely mixing scenarios do not account for paint sludge in the sediment because the ratio of observed PAHs in the paint sludge is unique and completely different from that observed in the sediment.

4) The PAH/SVOC evaluation included assessment of the relative proportion of PAH ring structures and phthalate contributions in paint sludge and the sediment sample. The relative proportion of phthalates in paint sludge samples is variable and ranges from approximately 9% to 80% (based on the sum of PAHs plus phthalates). As previously stated, PAHs in the paint sludges are dominated by 2-ring naphthalenes, whereas the sediment sample contains approximately 38% phthalates with the balance composed of a more even distribution of 2- through 6-ring PAHs. As indicated previously, the integrity of ratios and proportions must be maintained in complex mixtures when two complex mixture sources are combined in a third media, such as sediment. The distribution of these compounds is clearly different in the sediment as compared to the paint sludge samples as shown on Figure 3. Therefore, the conclusion is that the sediment does not appear related to paint sludge.

5) Metals evaluation indicates that lead is the dominant metal (of the 8 metals included) in paint sludge. Other predominant metals in the paint sludge include antimony, zinc, and chromium, with lesser contributions of copper, nickel, arsenic, and cadmium. In contrast, zinc is the dominant metal present in the sediment (approximately 47%), followed by lesser proportions of lead, copper, chromium, nickel, and arsenic, with negligible proportions of antimony and cadmium. As shown on Figure 4, the relative proportions of metals in the sediment do not match the proportions in the various paint sludge samples. Therefore, based on comparison of the metals ratios, the sediment does not appear to contain paint sludge

6) Cluster analysis of the metals data, based on proportions of the eight metals, clearly identify five distinct groups. The groupings are illustrated on the dendogram shown on Figure 5, and the specific samples in each group are identified by a colored dot above each sample on Figure 4. Two paint sludge sample groups (red dot and orange dots) are fairly unique based on composition, with the remaining paints sludges falling into two broad groups (green and blue dots). The sediment sample is the most unique of all samples and occurs in its own independent group. The geometric mean of these metal: zinc ratios is shown for each group on Figure 6. Ratios are much lower in the sediment for lead:zinc, chromium:zinc, and antimony:zinc in sediment, whereas they are typically much greater for copper:zinc, nickel:zinc, arsnic:zinc, and cadmium:zinc. In looking at the trend lines for these ratios, none of the groups for the paint sludge results are comparable to the sediment ratios. Because continuity of ratios is essential in mixing, it is concluded that the metals in the sediment are not likely derived from the paint sludges because there is no continuity of ratios.

7) VOC evaluation indicates that xylene dominant VOC is present in the sludge samples, with naphthalene, ethylbenzene, and toluene making up the majority of the balance of the VOC proportions. Where detected, benzene concentrations are fairly low in the sludge samples. This is in contrast with the sediment sample, which is dominated by a much higher relative proportion of naphthalene followed by xylene. The sediment sample is also unique as compared to the paint sludge sample due to the presence of benzene and absence of toluene and ethylbenzene that are present at fairly consistent proportions in the paint sludge samples. These relationships are shown on Figure 7.

8) A qualitative argument is provided related to the potential for benzene from paint sludge to be a source for benzene in groundwater found in the mine. It has been suggested by others that benzene could be migrating from the paint sludge to groundwater. This is highly unlikely for several reasons. First, paint sludge forms a hardened shell (a “rind”) where it is exposed to the environment (whether air or water), which essentially creates a barrier to the physical migration of constituents from the potentially soft interior of the sludge to the environment. Second, the absolute concentration of benzene in paint sludges is fairly low (where detected) and this is particularly true in comparison with other VOCs such as toluene and xylene that are present at much higher concentrations in the sludges. If benzene would be migrating from the interior of the paint sludges, it would be anticipated that other VOCs such as toluene, ethylbenzene, and xylene would also be migrating to groundwater and would be present at much higher concentrations. Because the other VOCs are not being detected in groundwater at concentrations that bear any

proportional relationship to the relative proportions of these constituents in the paint sludges, it is concluded that the source of benzene is not likely from paint sludge.

9) In conclusion, multiple lines of evidence have demonstrated that the sediments and paint sludge are not related. The data evaluated do not suggest that the paint sludges have contributed to the concentration of PAHs, phthalates, metals or VOCs in the sediment sample.

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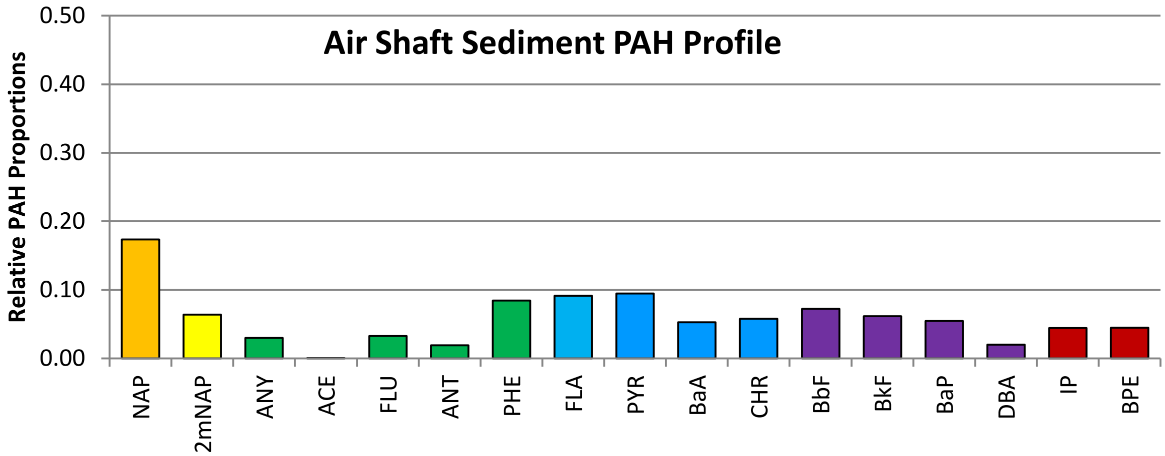
Table 1 – Summary of Samples used in Forensics Analysis

Date Sampled	Sample ID	Metals	PAHs	VOCs
3/30/87	EP-A1	Yes	Yes	Yes
3/30/87	EP-B1	Yes	Yes	Yes
3/30/87	EP-B3	Yes	Yes	Yes
3/30/87	EP-B5	Yes	Yes	No
4/1/87	EP-A4	Yes	Yes	No
4/1/87	EP-A9	Yes	Yes	Yes
4/1/87	EP-C1	Yes	Yes	Yes
4/1/87	EP-C4	Yes	Yes	Yes
4/1/87	EP-C7	Yes	Yes	Yes
12/16/04	SR-1	No	No	Yes
1/19/05	SR-2	No	No	Yes
1/19/05	SR-3	No	No	Yes
1/19/05	SR-4	No	No	Yes
1/19/05	SR-5	No	No	Yes
7/12/05	BLUE-GRAY PAINT	Yes	No	Yes
7/12/05	BLUE-RED PAINT	Yes	No	Yes
7/12/05	RED PAINT	Yes	No	Yes
8/19/05	SOIL-4	No	No	Yes
8/19/05	SOIL-G	No	No	Yes
8/22/05	SOIL-5	No	No	Yes
4/27/06	SR-7-PAINT SLUDGE	Yes	Yes	Yes
4/27/06	SR-8-PAINT SLUDGE	Yes	Yes	Yes
4/27/06	SR-9-PAINT SLUDGE	Yes	Yes	Yes
5/15/07	OC-SL3-070515	Yes	No	No
5/15/07	PMM-SL1-070515	Yes	No	No
5/15/07	PMM-SL2-070515	Yes	Yes	No
5/15/07	SR6-SL4-070515	Yes	No	No
5/15/07	SR6-SL5-070515	Yes	No	No
8/31/07	SR6-PS-070831-1	Yes	Yes	Yes
8/31/07	SR6-PS-070831-2	Yes	Yes	Yes
10/20/11	**PMPAIRSHAFT-SED**	Yes	Yes	Yes
	Samples Included	23	16	24
	Percent of sample suite	74.2%	51.6%	77.4%



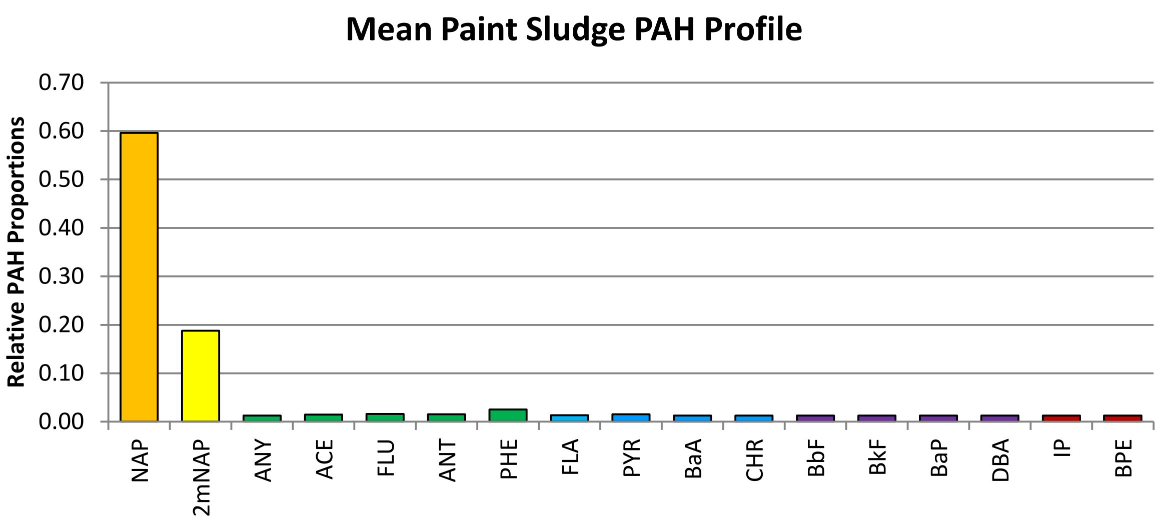


Figure 1. Normalized PAH proportions for the Airshaft Sediment sample, and the mean PAH proportions for 18 Paint Sludge samples. The Airshaft Sediment sample is characterized by a broad range of PAH ring structures, whereas the Paint Sludges are dominated by 2-ring naphthalenes with other PAHs generally contributing <2% to the total mass of PAHs.

2-Ring PAHs

NAP	Napthaltlene
2mNAP	2Methylnaphthalene

3-Ring PAHs

ANY	Acenaphthylene
ACE	Acenaphthene
FLU	Fluorene
ANT	Anthracene
PHE	Phenanthrene

4-Ring PAHs

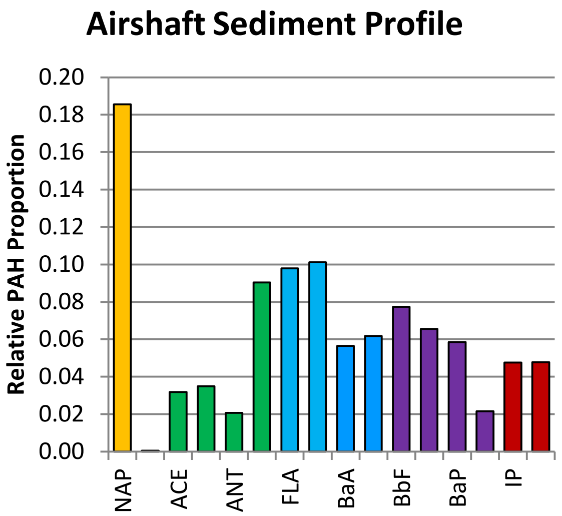
FLA
PYR
BaA
CHR

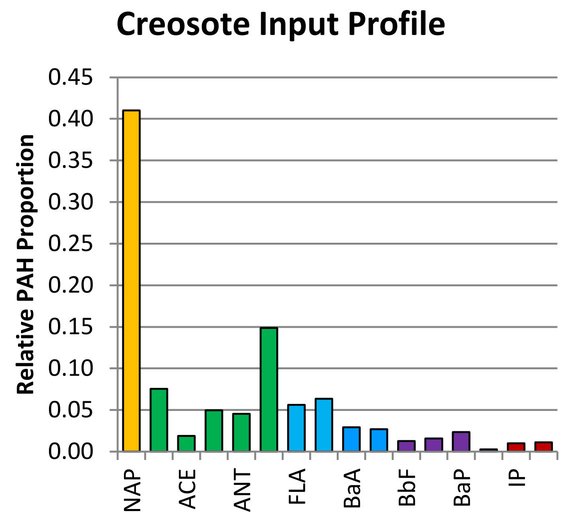
5-Ring PAHs

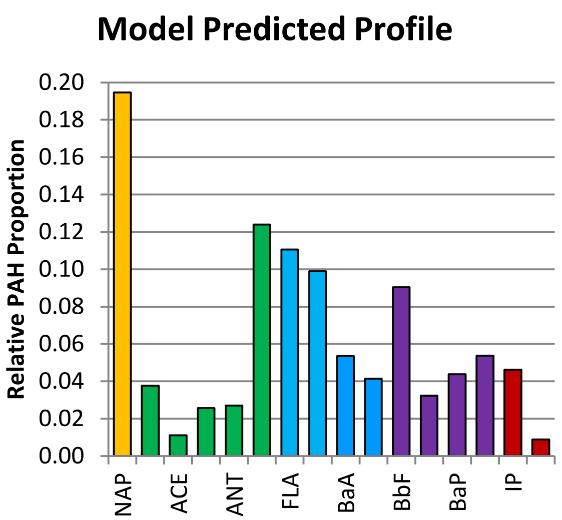
BbF
BkF
BaP
DBA

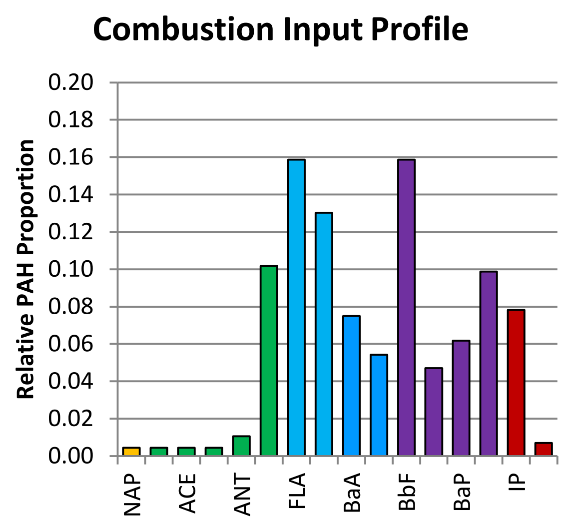
6-Ring PAHs

IP	Indeno(cd-123)Pyrene
BPE	Benzo(g,h,i)Perylene









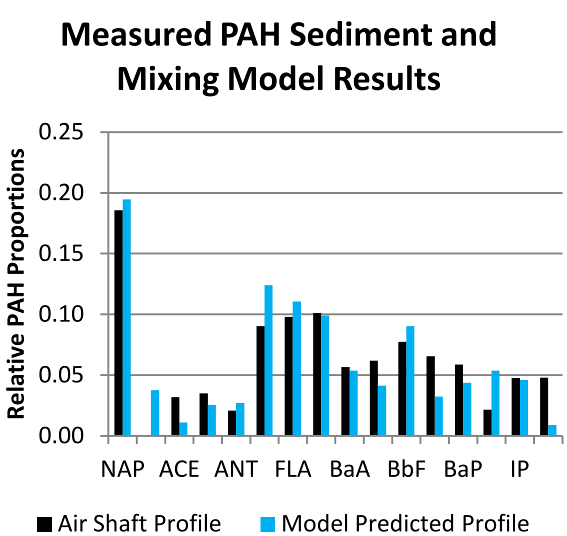


Figure 2. Mixing Model Results. Upper left profile shows measured PAH sediment profile. Upper and lower right profiles represent creosote and combustion source PAH profiles. Middle left shows best-fit mixing model results with 47% creosote source material and 53% combustion source profile. Lower left provides a side-by-side comparison of the measured PAH distribution in sediment and the mixing model results.

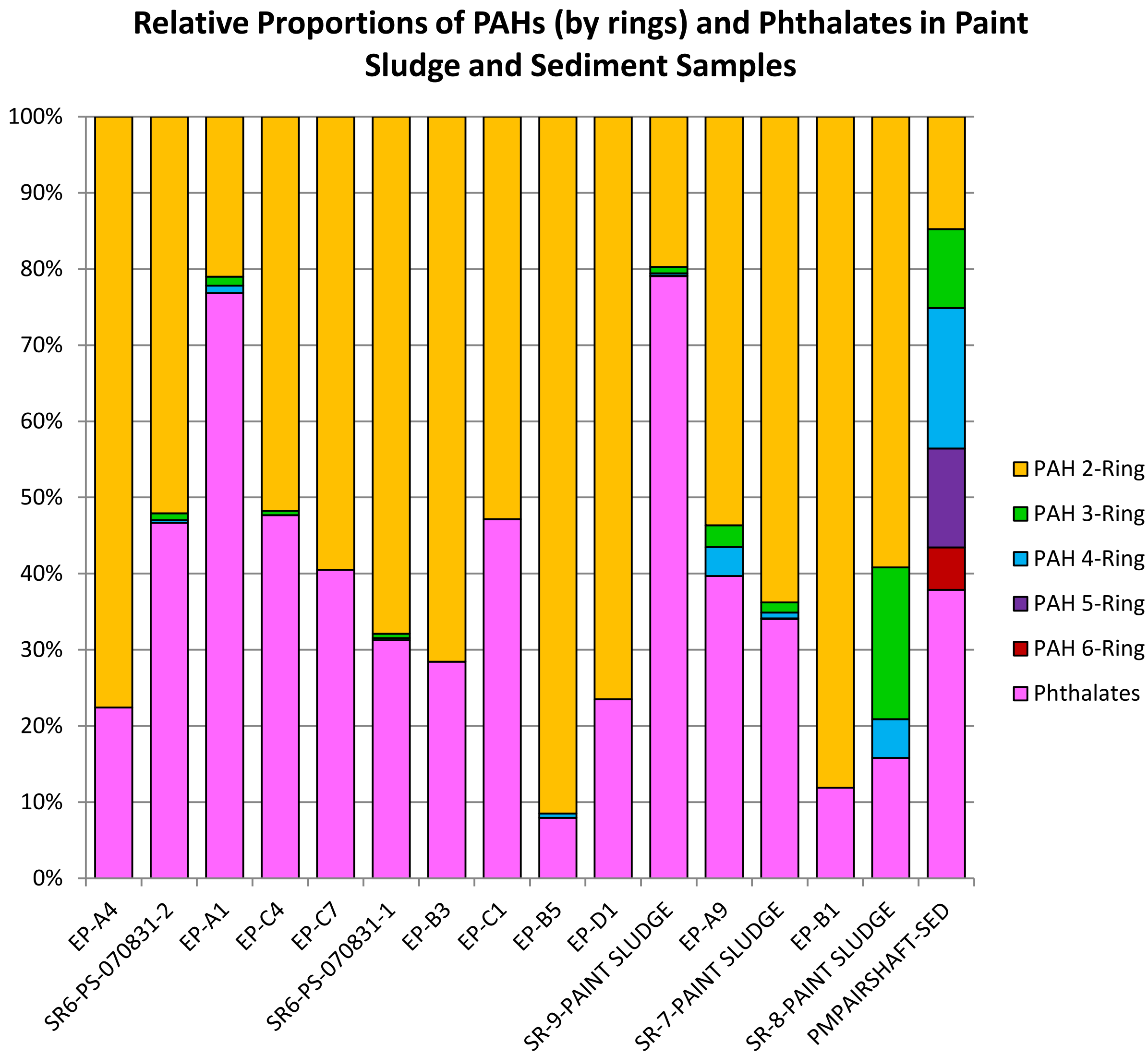


Figure 3. PAH and SVOC distributions by sample. Illustrates the relative proportions of PAH compounds, by ring structure, and phthalates. Paint sludge samples are predominantly composed of a mixture of phthalates and 2-ring PAHs.

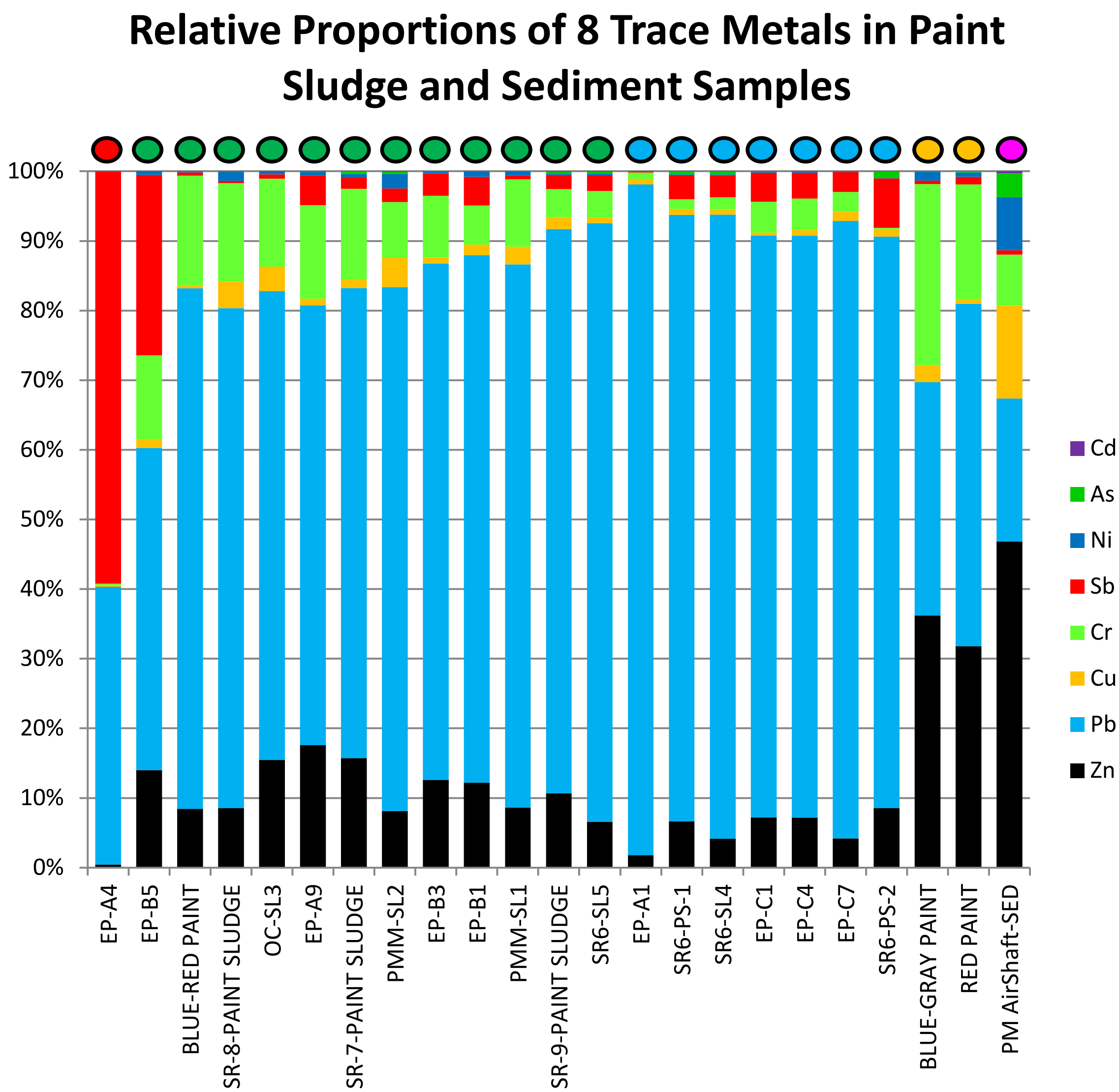


Figure 4. Relative proportions of 8 metals in paint sludge samples and sediment sample. Samples are ordered according to cluster analysis similarity factors as shown on the following graph. Colored dots represent the cluster group.

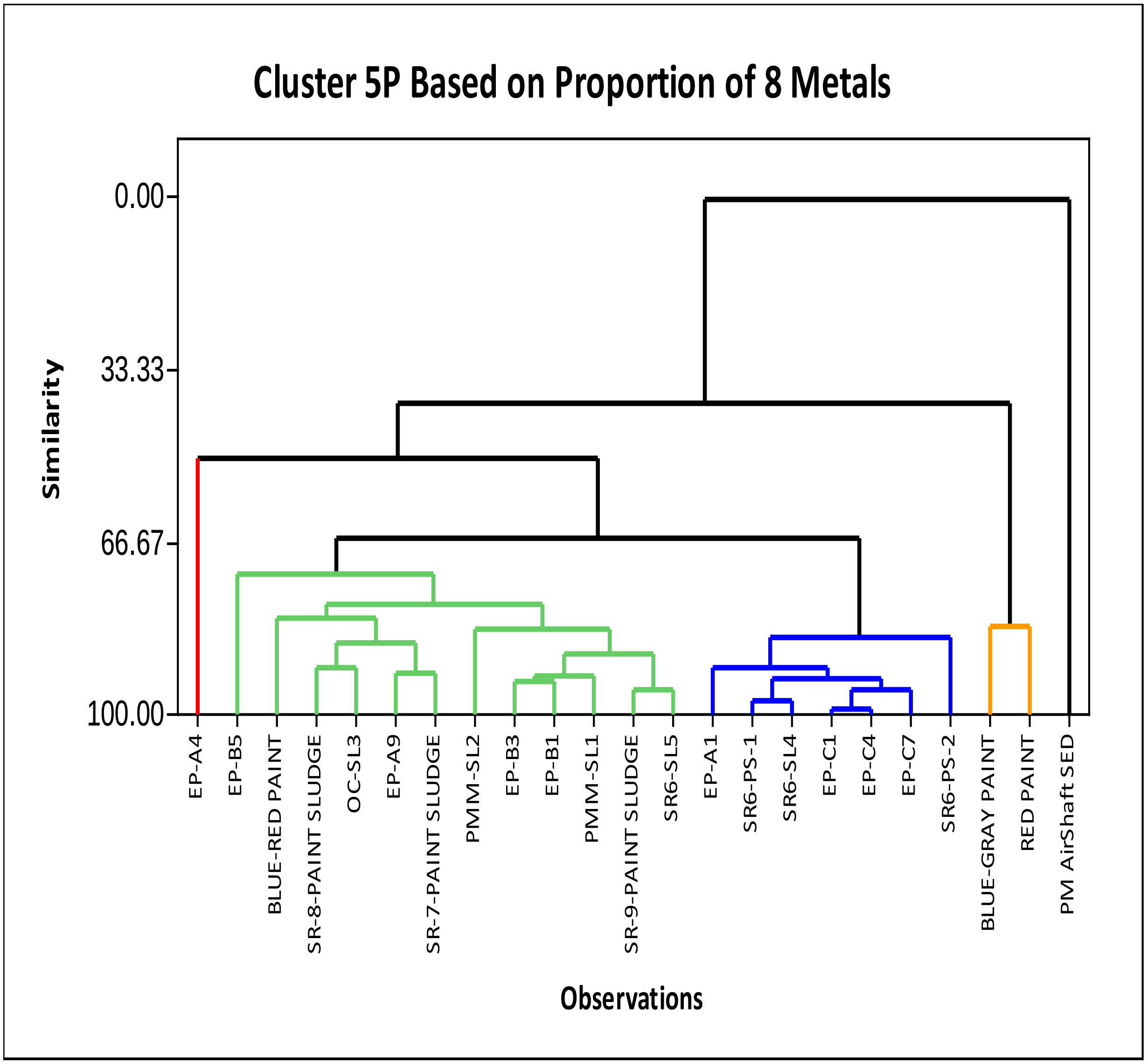


Figure 5. Cluster Analysis results of paint sludge samples and sediment . Cluster groups were calculated based on Pearson Distance and "Farthest Neighbor" linkage method to ensure effective identification of the most unique samples. The similarity is based on the multivariate Pearson distance between any two individual samples, or successive clusterings within a group.

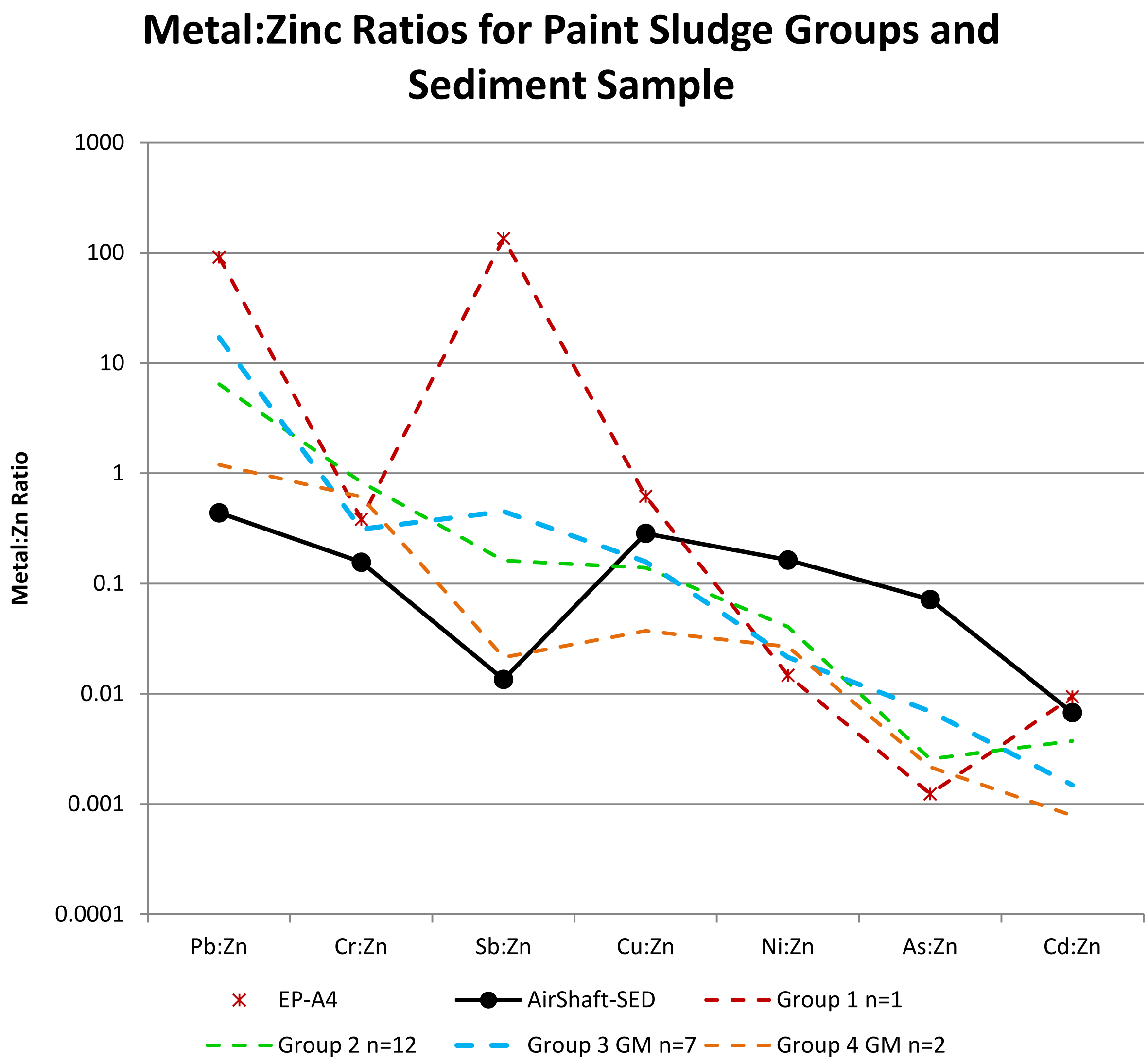


Figure 6. Metal:Zn ratios. Geometric mean metal:Zn ratios are plotted for the four cluster groups of paint sludge results as compared to the metal:Zn ratios for the Air Shaft sediment sample. Ratios are much lower in the sediment for Pb:Zn, Cr:Zn and Sb:Zn in sediment, whereas they are typically much greater for Cu:Zn, Ni:Zn, As:Zn, and Cd:Zn. In looking at the trend lines for these ratios, none of the groups for the pairing sludge results are comparable to the sediment ratios. Because continuity of ratios is essential in mixing, it is concluded that the metals in the sediment could not be derived from the paint sludges.

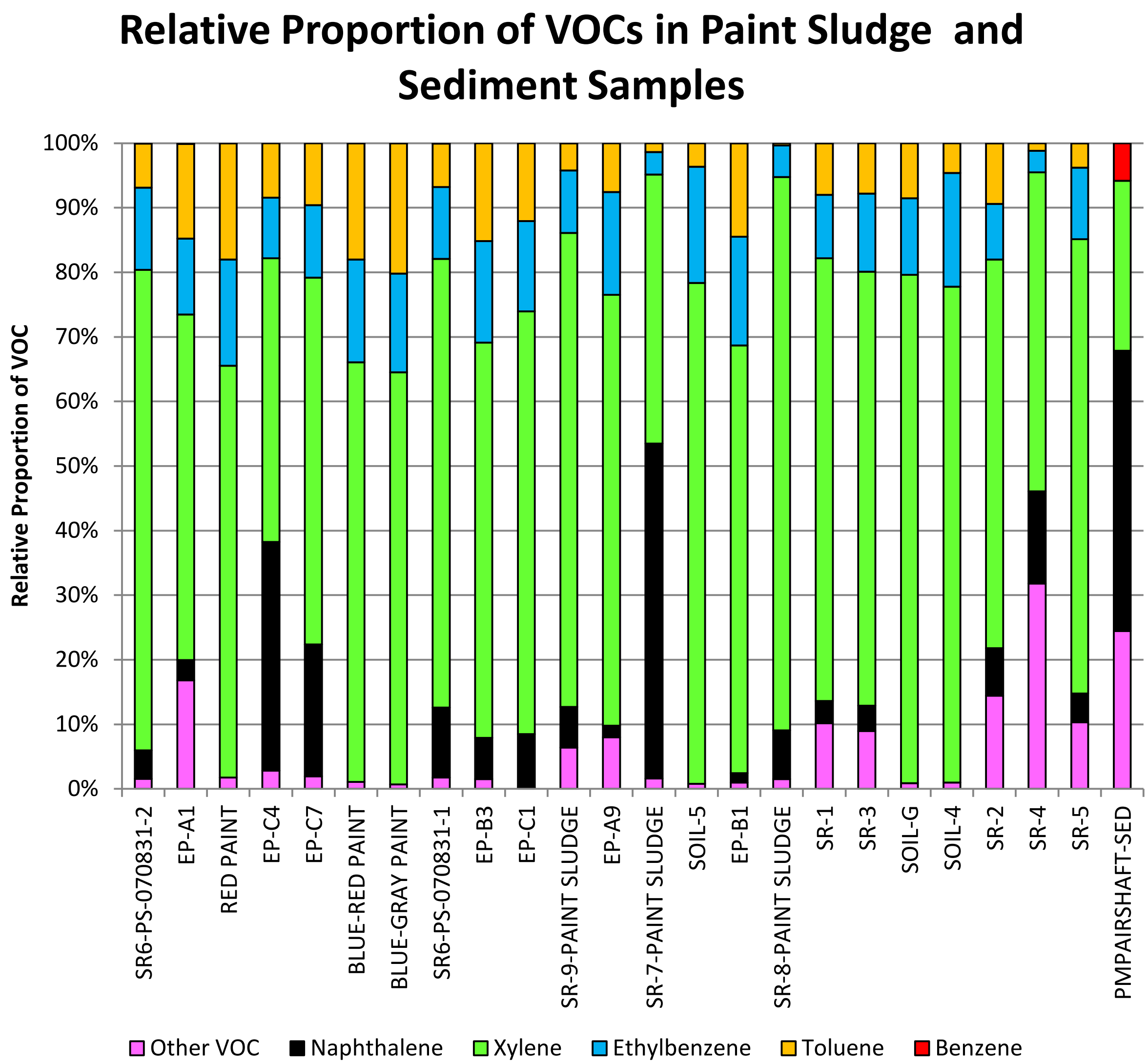


Figure 7. VOC distributions by sample. Illustrates the relative proportions of benzene, toluene, ethylbenzene, xylenes, naphthalene, and other VOCs. Paint sludge samples are dominated by xylenes and xylenes plus naphthalene, along with ethylbenzene and toluene. The sediment sample is dominated by naphthalene with lesser amounts of xylenes, benzene ,and other VOCs. Toluene and ethylbenzene are essentially absent from the sediment sample, whereas they are present in appreciable proportions in all paint sludge samples. Therefore, the VOCs in the sediment are not related to the VOCs in the paint sludge samples.

Figure I-1. PAHs in Paint Sludge Samples

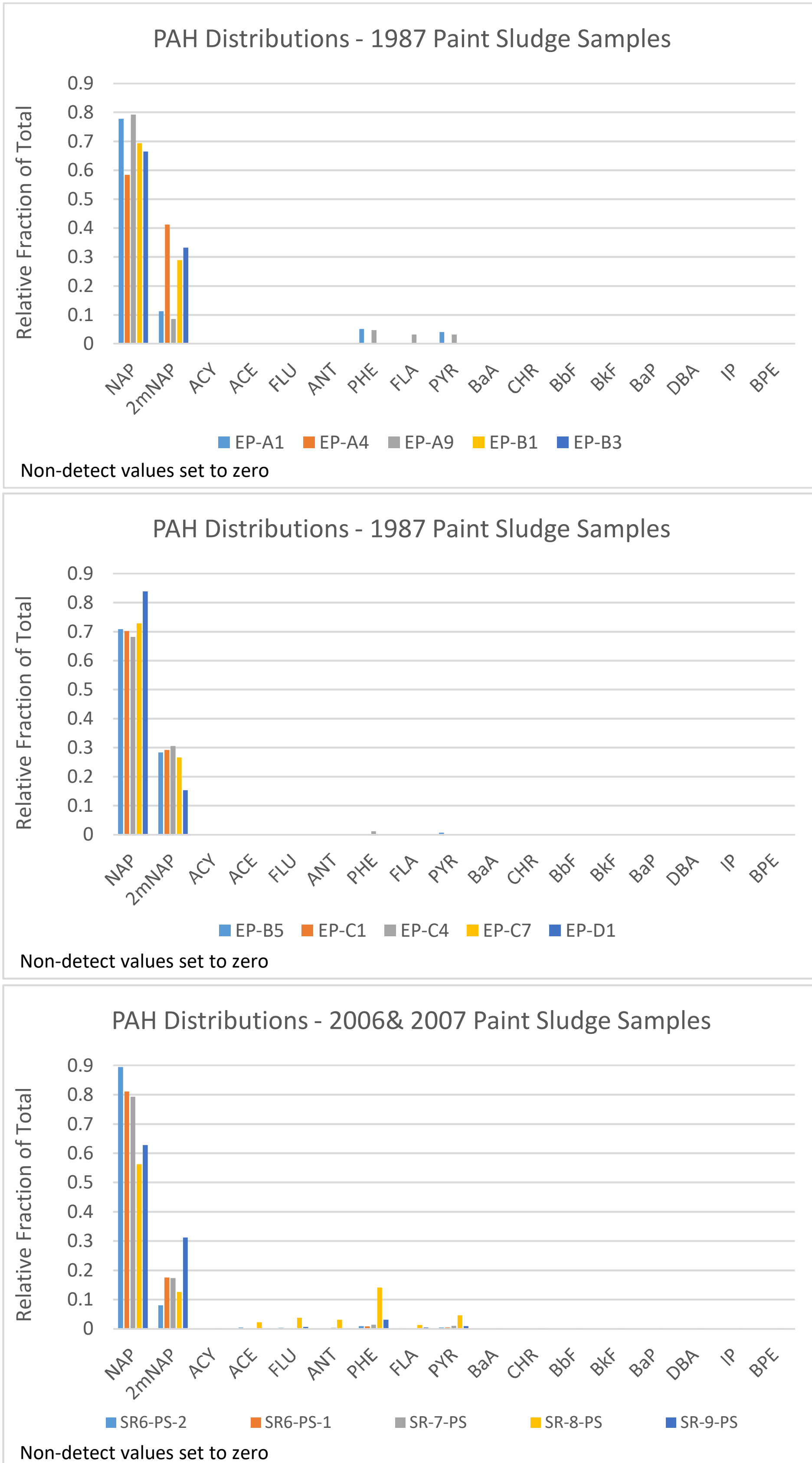
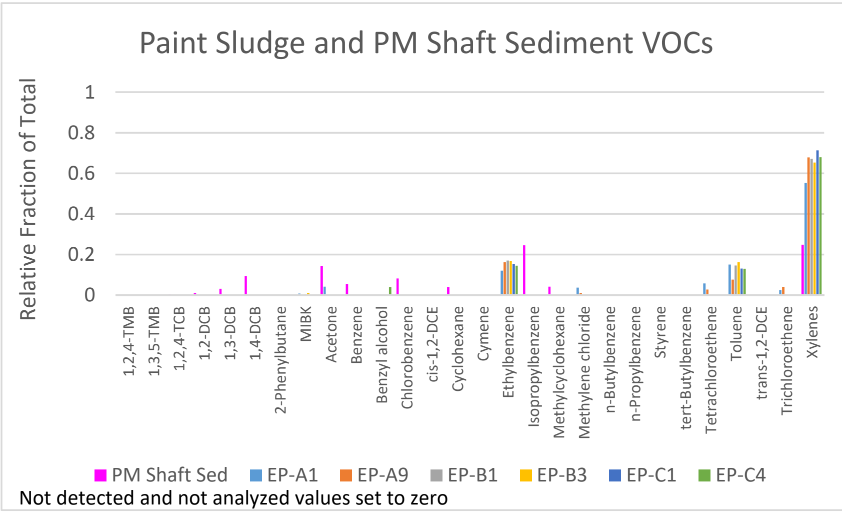
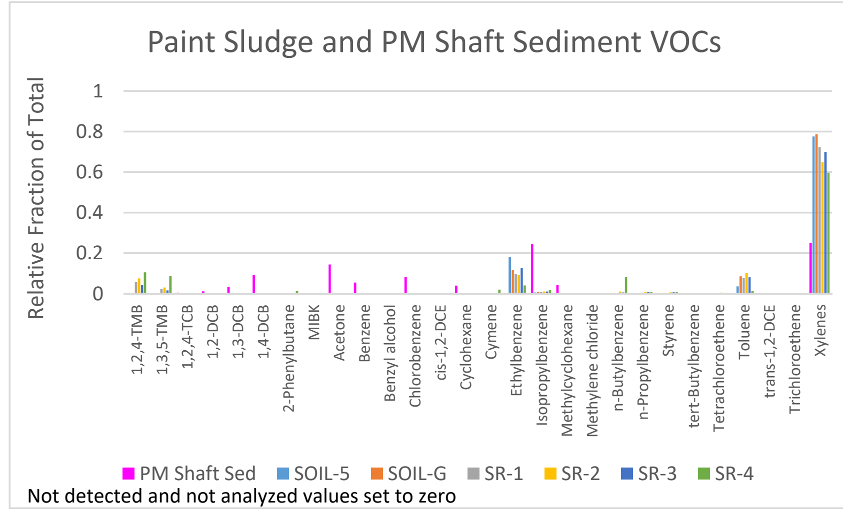
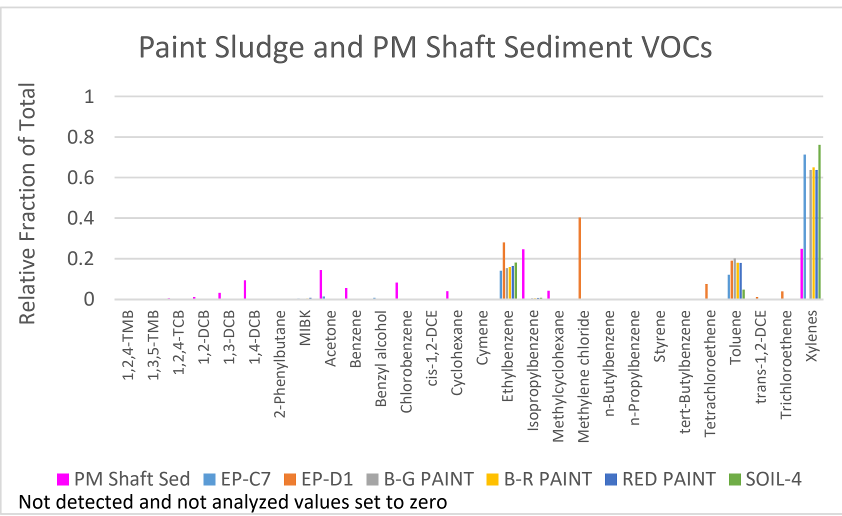


Figure I-2. Comparison of PAHs in Paint Sludge and PM Shaft Sediment Samples

Figure I-3. Comparison of VOCs in Paint Sludge and PM Shaft Sediment Samples







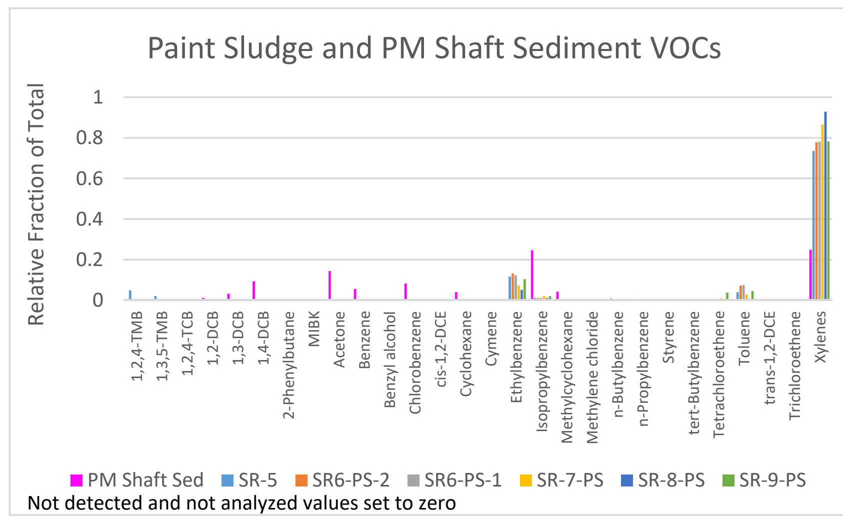
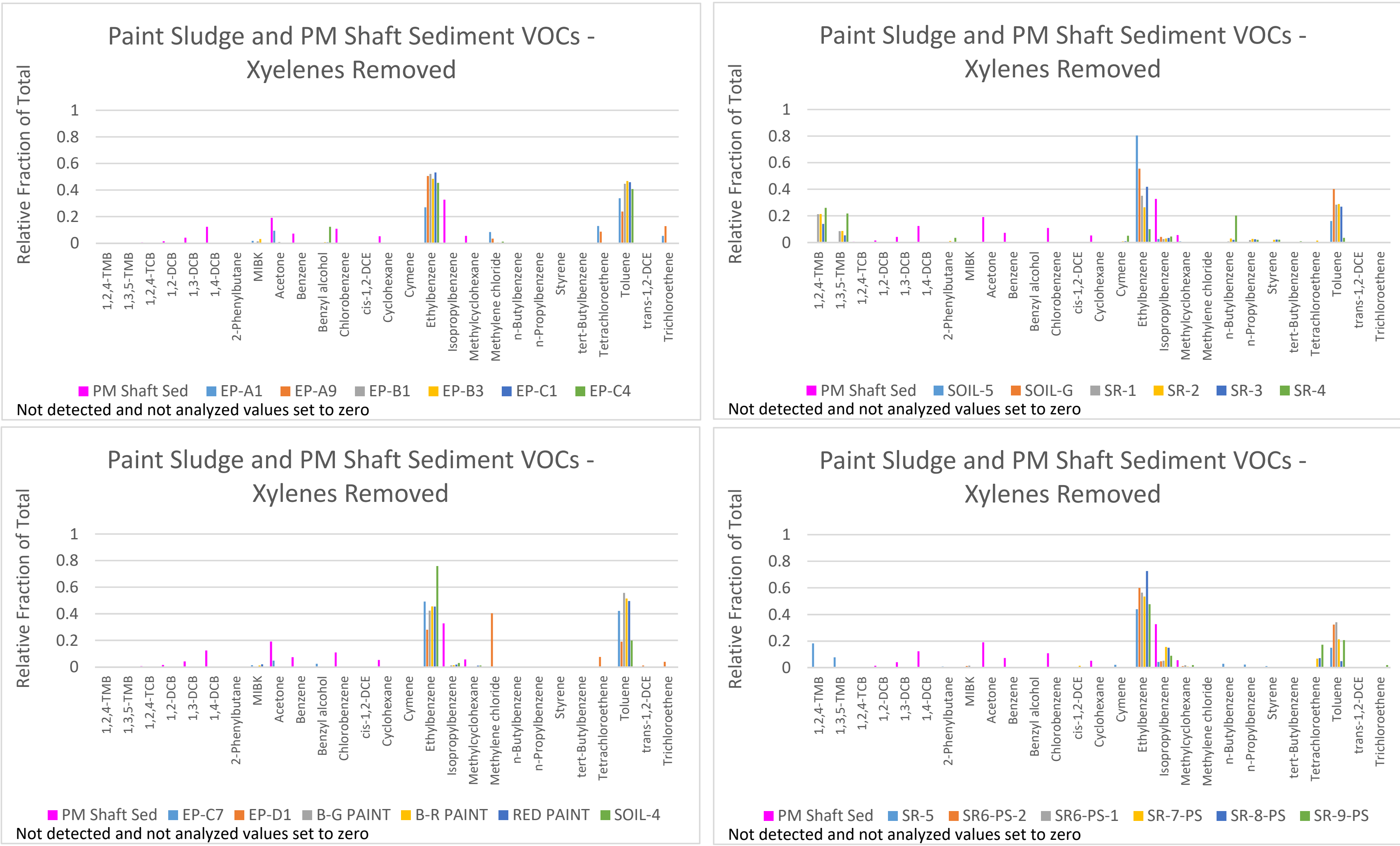


Figure I-4. Comparison of VOCs in Paint Sludge and PM Shaft Sediment Samples Excluding Xylenes



Consideration of Pilot Test for Benzene in the Peters Mine Air Shaft

Ringwood Mines/Landfill Site
Ringwood, New Jersey

May 22, 2013

Introduction

ARCADIS

Joseph Quinnan, PE, PG

- With ARCADIS since 2000
- Director, Site Investigations Service Area
- Located in Brighton, MI Office
- Areas of expertise:
  - Site Characterization
  - Remediation Hydrogeology
  - In-Situ Remediation
- Member of ITRC “DNAPL Site Characterization” Team
- Co-author, ***Remediation Hydraulics*** (CRC, 2008)

Evaluation of Pilot Test

- **Current system is containing and naturally degrading benzene**
  - It is protective
  - Stratification of flooded mine works is common
  - Now that works are flooded, stability of stratification is expected for long term
- **Thermocline is technically defensible**
  - Founded in Limnology and mining
  - Flow meter data cannot be relied upon to assess flow in air shaft

Evaluation of Pilot Test

Performing pilot test has several risks

- Implementation of pilot could upset stratification that is containing and degrading benzene
  - Could enable transport of benzene to shallow system
  - Could change flux conditions in deep zone (i.e. change partitioning rate from sediment into water)
- Indicates/implies that current conditions are not protective

Historical Pumping from PM Air Shaft–

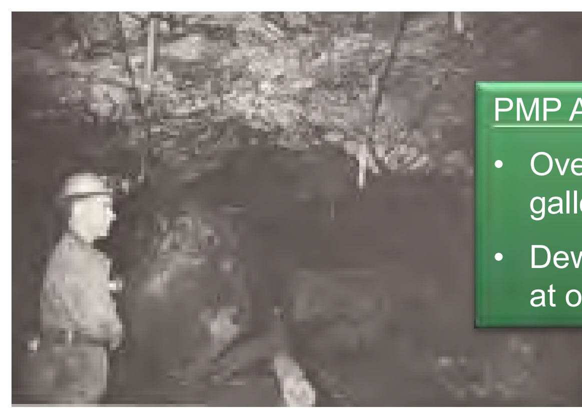
October 1980:

- Ringwood Fire Department pumped 420,000 gallons from air shaft over several days
  - Installed pipes to bottom of shaft (to facilitate lowering pumps)
  - Pumping occurred at base of shaft

- Water sample from 225 feet bgs revealed presence of 19 ug/l benzene
  - When the sample was collected is unclear (i.e. at the start, middle or end of pumping event)

Provides insight on possible outcome of proposed pilot test

- Pilot study will not resolve questions on source area



PMP Area facts:

- Over 213,000,000 gallons of capacity
- Dewatered by pumping at only 50 gpm

Images taken from *Vanishing Ironworks of the Ramapos*, James M. Ransom
Published by Rutgers University. 1966

Evaluation of Pilot Test

What will EPA's recommended quiescent pumping or aeration do?

- It will upset stratification
- It will introduce multiple variables
- Would require protracted efforts to make pilot work
- Would require **long-term operations** and monitoring to demonstrate if pilot program can be stable

If the pilot test does not work, we cannot determine why it failed

- For example, is the source the water from mine workings and not the sediment? Is it fire? Is it abandoned timbers?

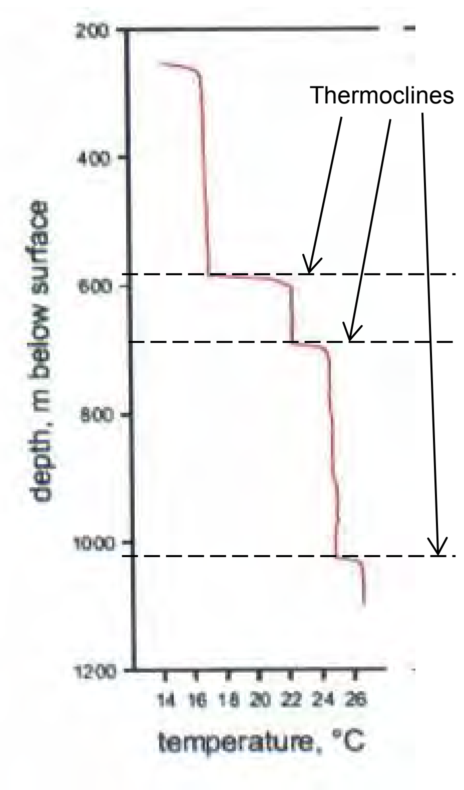
Overview

Multiple lines of evidence confirm the natural system is **containing** and **degrading** the limited amount of benzene present in the deeper water

- Determined that flow meter data cannot be relied upon to assess flow in air shaft
- Thermal and geochemical **stratification** of water in shaft
- Absence of benzene above the depth of stratification
- Confirmed biological activity capable of degrading benzene in the water column above and below the depth of stratification

Hydraulics of Abandoned Mines

- **Stratification of flooded mine works is common**
  - Founded in Limnology principles
  - Observed in flooded mines
- **Based on:**
  - In-situ measurements of hydrodynamic processes in flooded mines
- **Stratification can be stable in isolated/deep mine workings**



(Example of geophysical profile, taken from Water Management at Abandoned Flooded Underground Mines, Wolkersdorfer, 2008)

CSM PM Air Shaft- Lines of Evidence

- **Thermocline**
- **Chemocline**
- **Benzene Distribution**
- **Geochemistry**
- **BioTrap data**

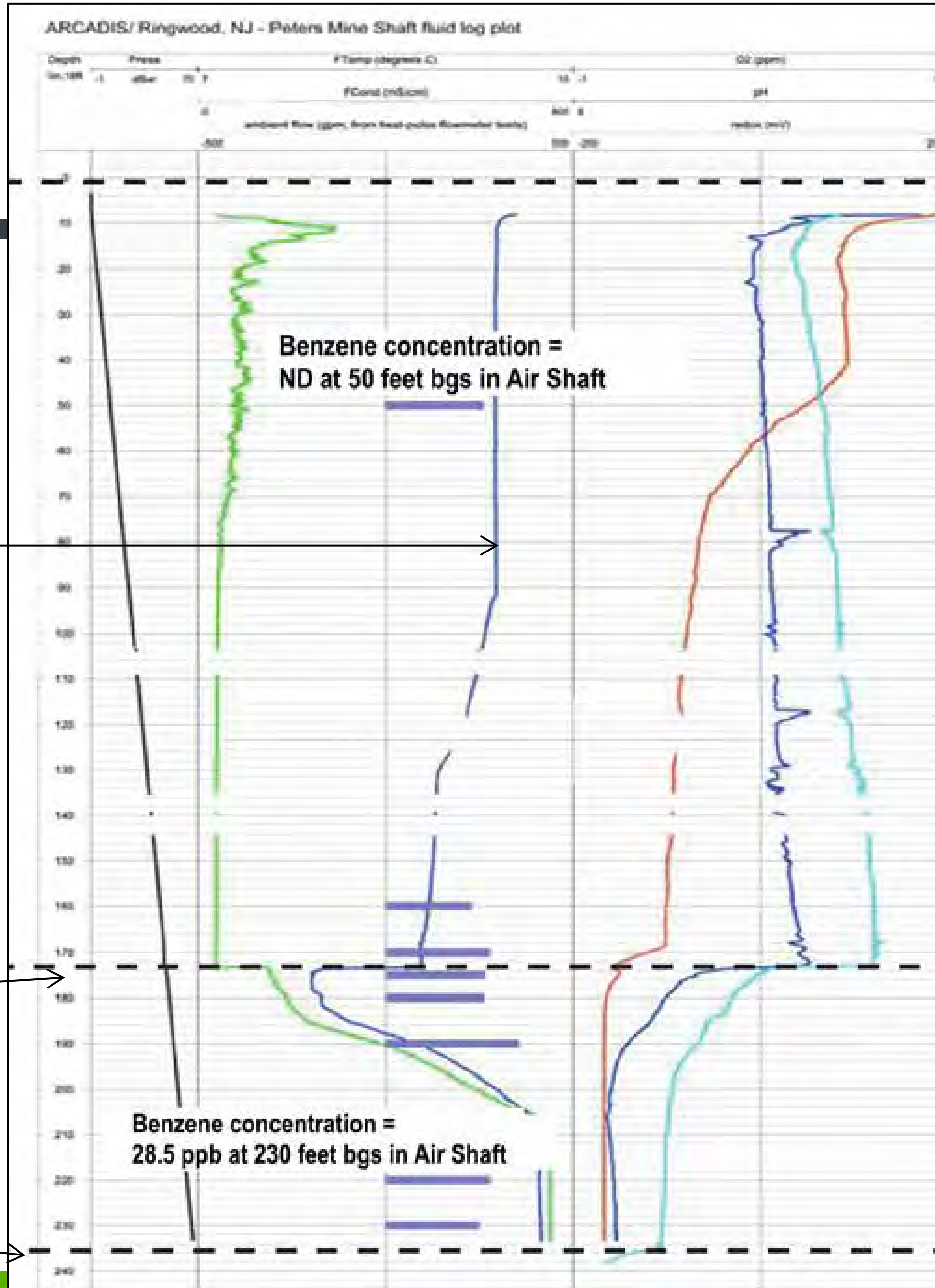
Chemocline + Thermocline = Stratification

PM Air Shaft

Temperature

Thermocline/ Chemocline

Base of Air Shaft



July 2012 Data

50feet:

Dissolved Fe = 14 ppb
Total Fe = 320 ppb

Dissolved Mn = 8.5 ppb
Total Mn = 103 ppb

D.O. = 5.28 ppm
Redox = 225 mv

180 feet:

Dissolved Fe = 136 ppb
Total Fe = 609 ppb

Dissolved Mn = 4.2 ppb
Total Mn = 14 ppb

D.O. = 3.5 ppm
Redox = 214 mv

230 feet:

Dissolved Fe = 108,000 ppb
Total Fe = 133,000 ppb

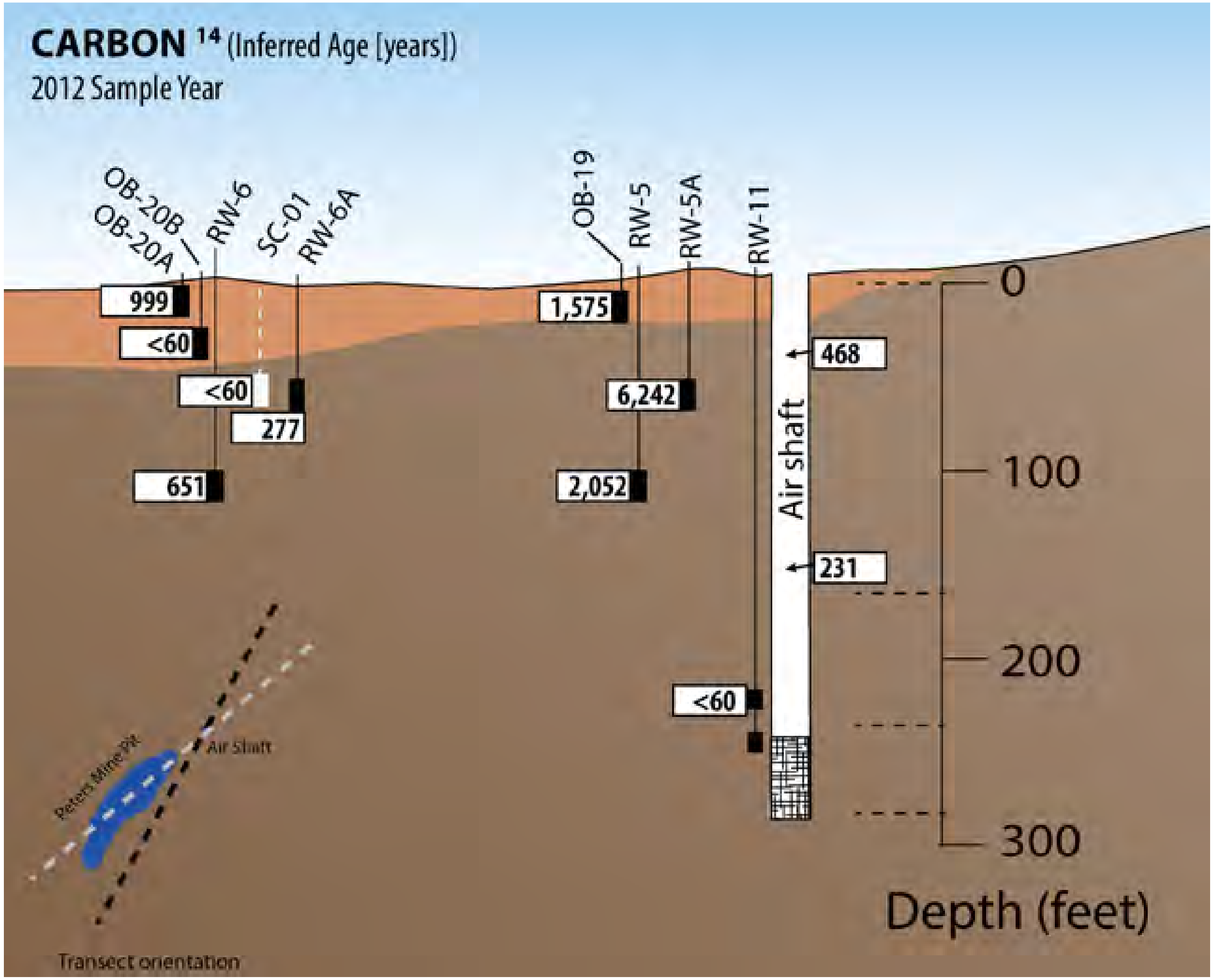
Dissolved Mn = 2,200 ppb
Total Mn = 2,270 ppb

D.O. = 1.05 ppm
Redox = -88mv

CSM PM Air Shaft – Lines of Evidence

CARBON^{14} 2012

- **Mix of modern and old water yields composite age in air shaft**
- **“Older” ages in overburden wells show old water moving from bedrock into overburden**
- **“Modern” signature in pit indicates preferred pathway to OB-20B**



CSM PM Air Shaft – Lines of Evidence

Hydraulics

- Water level elevations taken from the air shaft and SC-01 (screened within lower third of mine pit) are essentially the same, but age dating indicates a limited connection to pit

- Water level in Air shaft is above surrounding shallow bedrock wells:
  - Limited connection between the mine workings and shallow bedrock

Summary

Multiple lines of evidence show that the benzene is contained and is degrading naturally

- Stratification prevents mixing of shallow water with deep water
- Biodegradation shown by benzene trends, geochemistry and Biotrap™ results
- Negligible communication between deeper air shaft and surrounding bedrock based on hydraulics and isotopes

Forensics Analysis Overview

Forensics

- Conduct an evaluation of PM Air Shaft sediment to determine if it is a potential source of COCs in water
- Consider multiple lines of evidence

  “build a table”, where lines of evidence = legs

- Evaluate if there is a reasonable association between paint sludge samples and the sediment sample

Overview of approach

1. Compared composition of sediment sample from base of PM Air Shaft to paint sludge samples
2. Conducted ratio analysis to evaluate and compare composition of samples
3. Considered mixing scenarios with other known sources of COCs at the Site

Forensics Analysis Overview

Methods

- Direct Comparison of PAHs
  - Type and Relative PAH Proportions
- Cluster Analysis of Metals
  - Statistical approach that groups samples based on the overall similarity in composition
- Direct Comparison of Metals Concentration and Distribution
- VOCs analysis

Data

- Sediment Sample
- Paint Sludge Samples
  - One sample is removed from some of the metals comparative analyses as it was not analyzed for zinc
  - Up to 25 metals were analyzed for the sludge samples, however, the analytical suite varied between sampling events. A final suite of 8 metals (Sb, Cu, Pb, Zn, Cr, Cd, Ni, and As) were selected for subsequent statistical analysis based on frequency of analysis and frequency of detection
  - PAH evaluation was based on the 16 Priority Pollutant PAHs plus 2-methyl naphthalene
- Metal Analyses in materials from Mine Tailings Investigation Report, May 2008

Forensic Analysis Mixing Model for PAHs

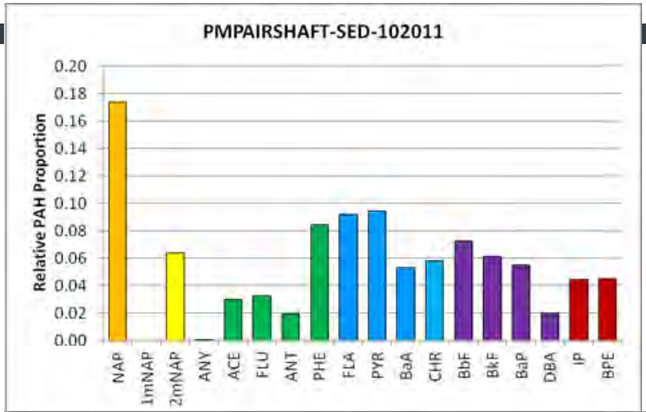
Sediment Sample Most Consistent with Mix of MGP and Combustion Sources

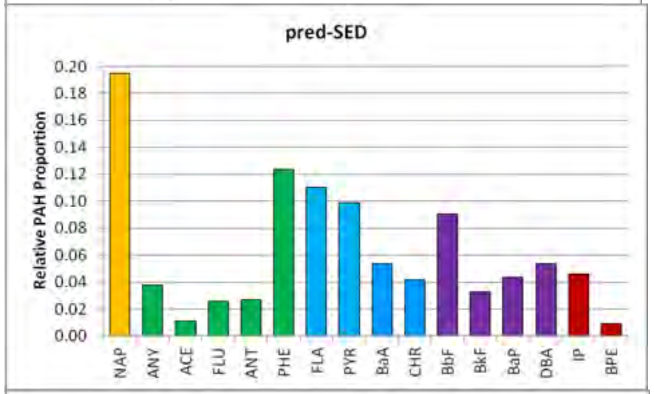
Mixing model (predicted sediment) using MGP (creosote) and urban dust/combustion-related PAH source materials

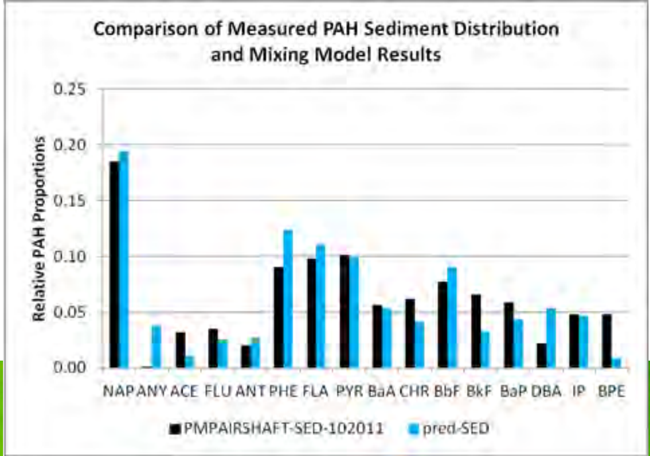
- Fundamental Principles of mixing calculations:
  - Relative proportions of dominant constituents must be retained

- Mixing profile compares well with the sediment sample with roughly 47% creosote and 53% combustion material (shown in the side-by-side comparison)
  - Relative PAH Proportions match well
  - PAH Spectrums match well

There is no other plausible mixing scenario (paint sludge + other source) that matches the observed spectrum of PAHs in the sediment sample



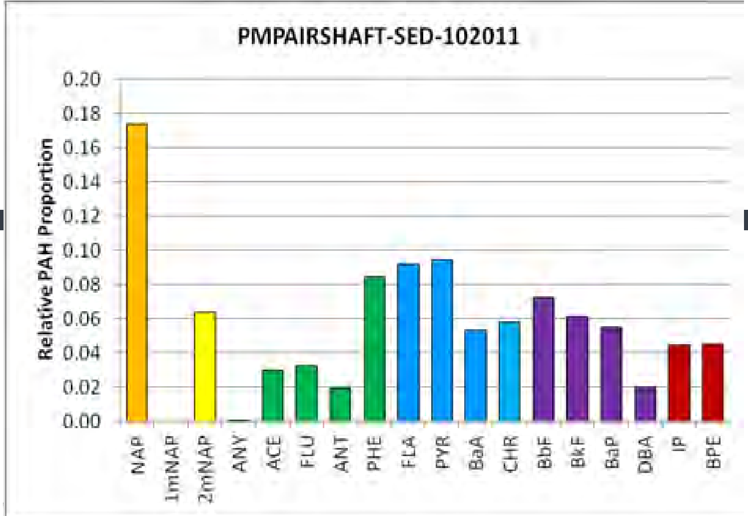


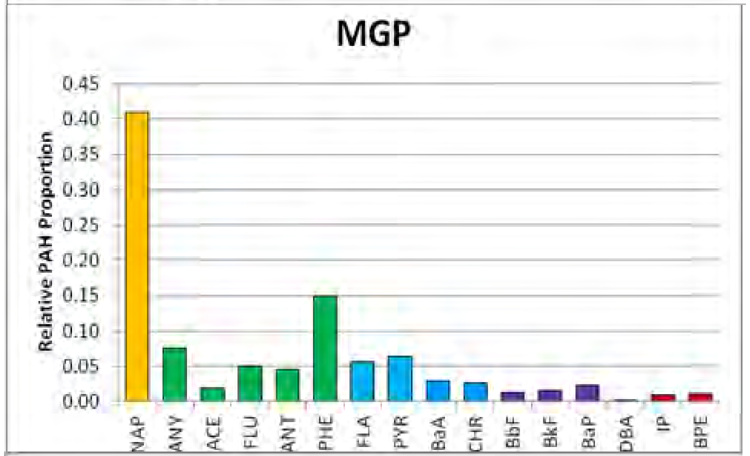


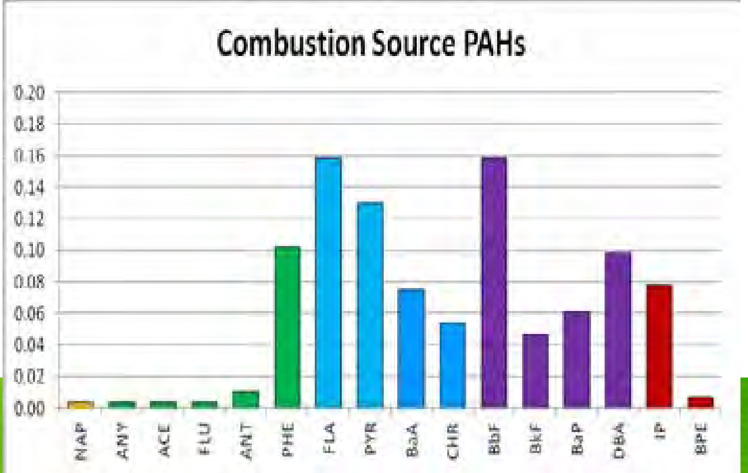
Forensic Analysis PAHs

Sediment Sample More Similar to MGP and Combustion Sources

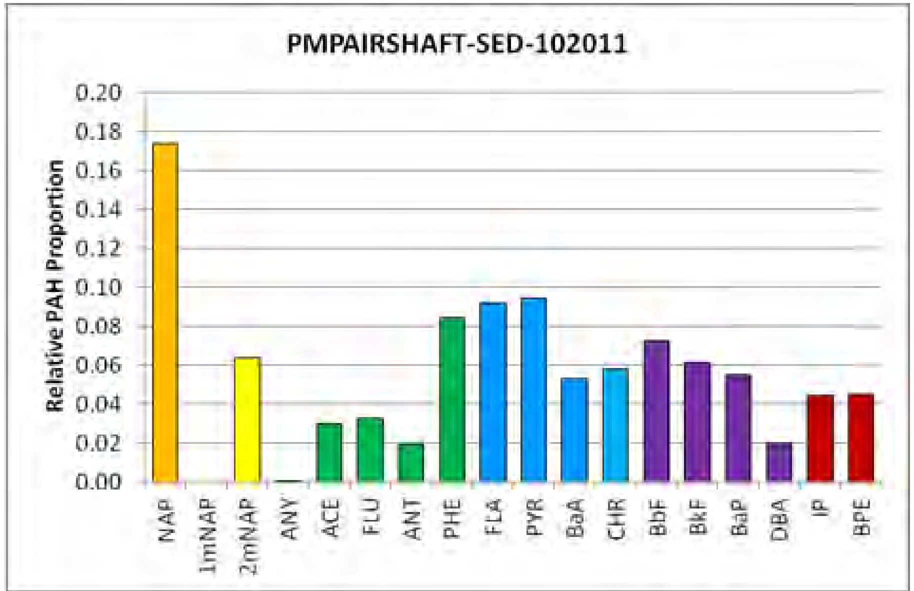
- Sediment is more similar to MGP and combustion PAHs (urban dust)
- Spectrum also similar to diesel contaminants and combustion PAHs (urban dust)- *not shown*

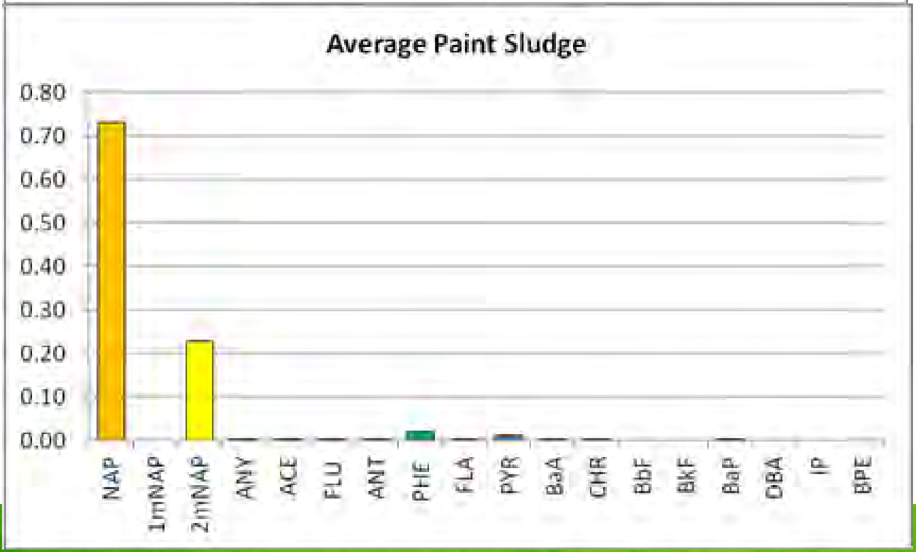






Forensic Analysis PAHs

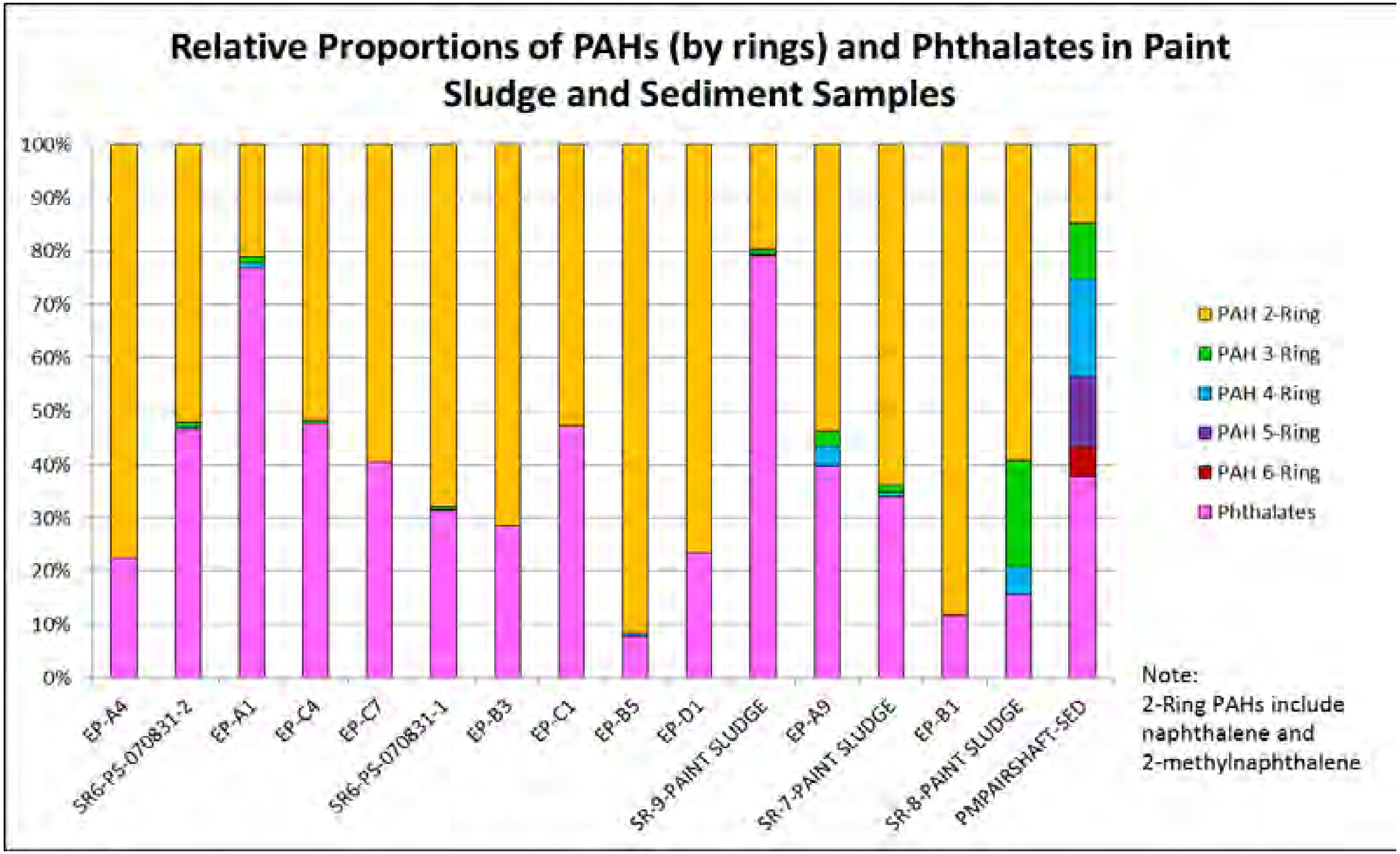




Sediment Sample Compared to Average Paint Sludge

- PAH Profile for “average” paint sludge
  - ü Dominance by naphthalene and 2-methylnaphthalene
  - ü Traces or non-detect of other PAHs
- Profile of paint sludge is very different from sediment sample
  - ü Relative PAH Proportions very different
  - ü Paint Sludge does not contain the full spectrum

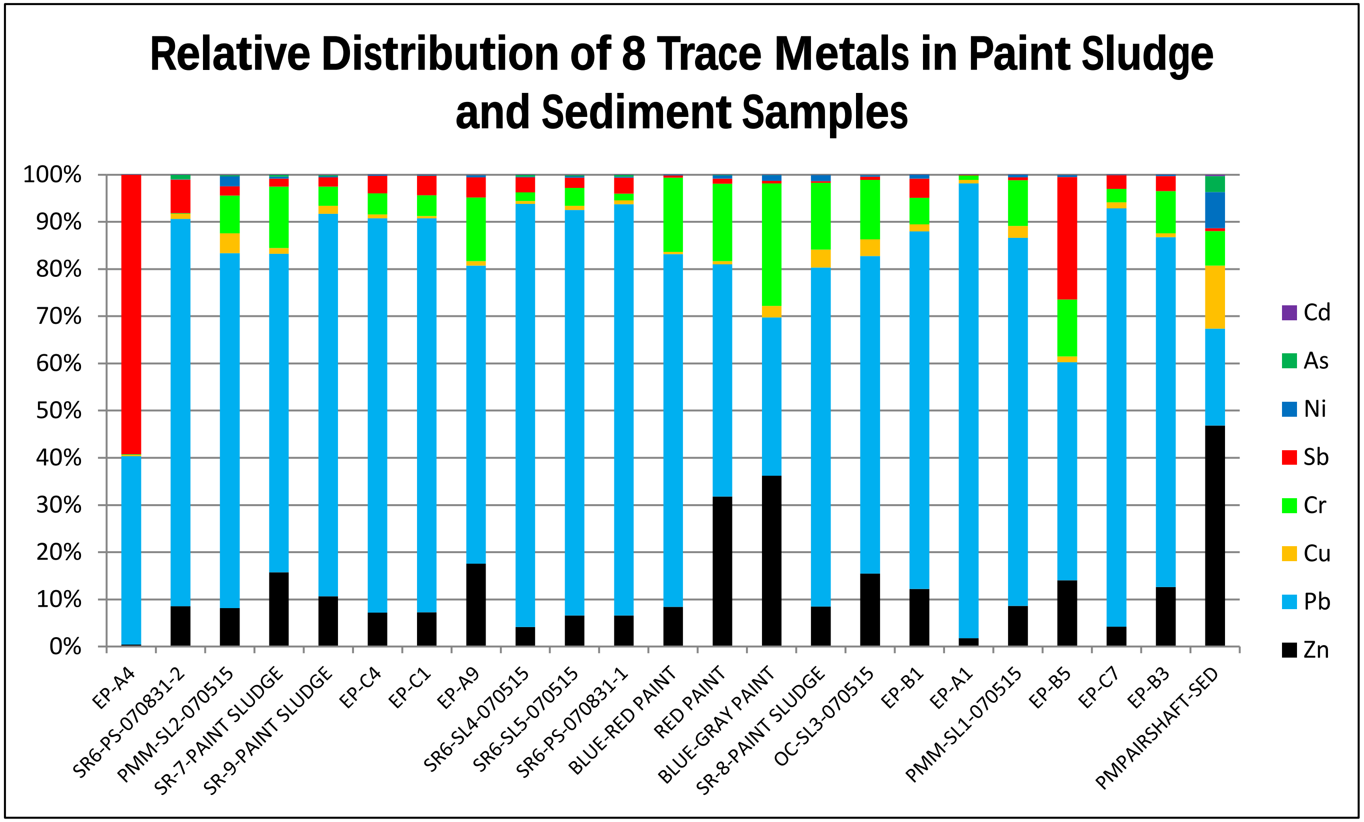
Forensic Analysis PAHs
Sediment Sample is Not Paint Sludge



- Paint sludge contains larger proportions of naphthalene

Forensic Analysis Metals

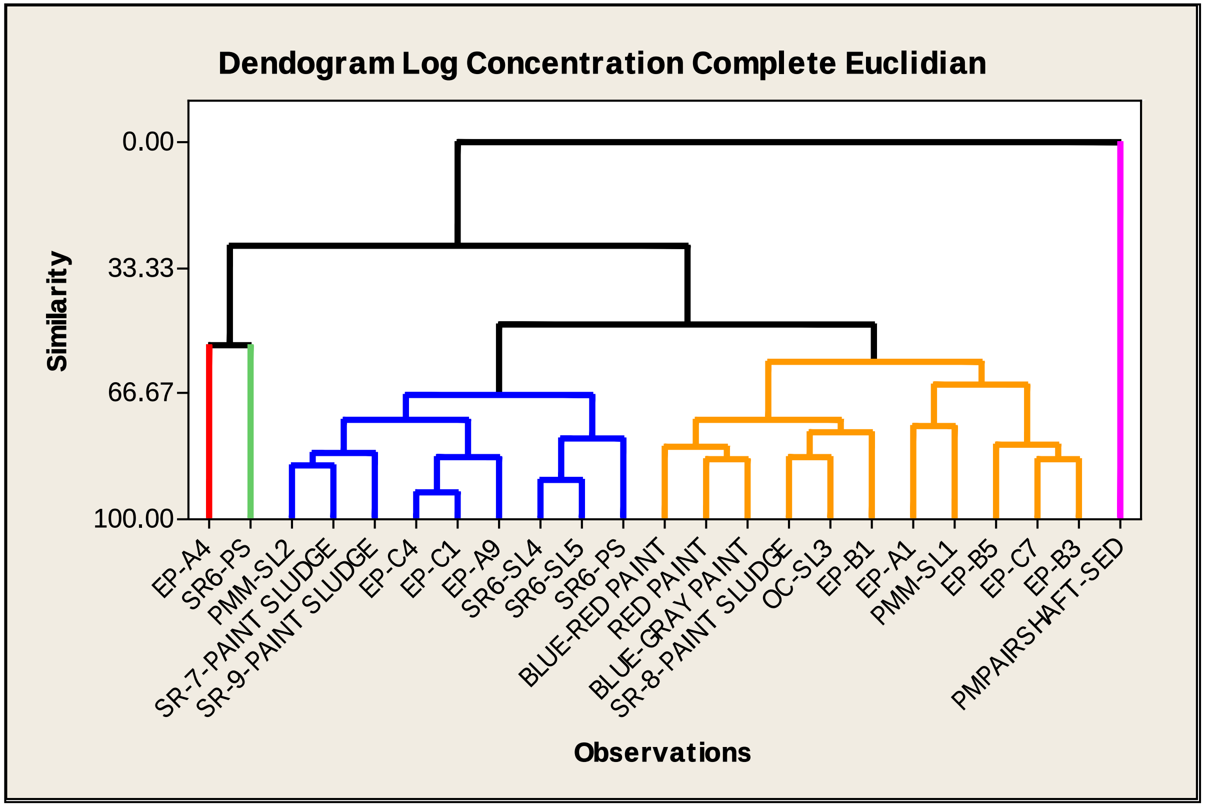
Paint Sludge is Not Part of the Sediment Mix



- Lead is dominant metal in paint sludge with relatively higher proportions of antimony and chromium
- Zinc is the dominant metal in sediment with higher relative proportions of copper, nickel and arsenic, and lower relative concentrations of lead and chromium.

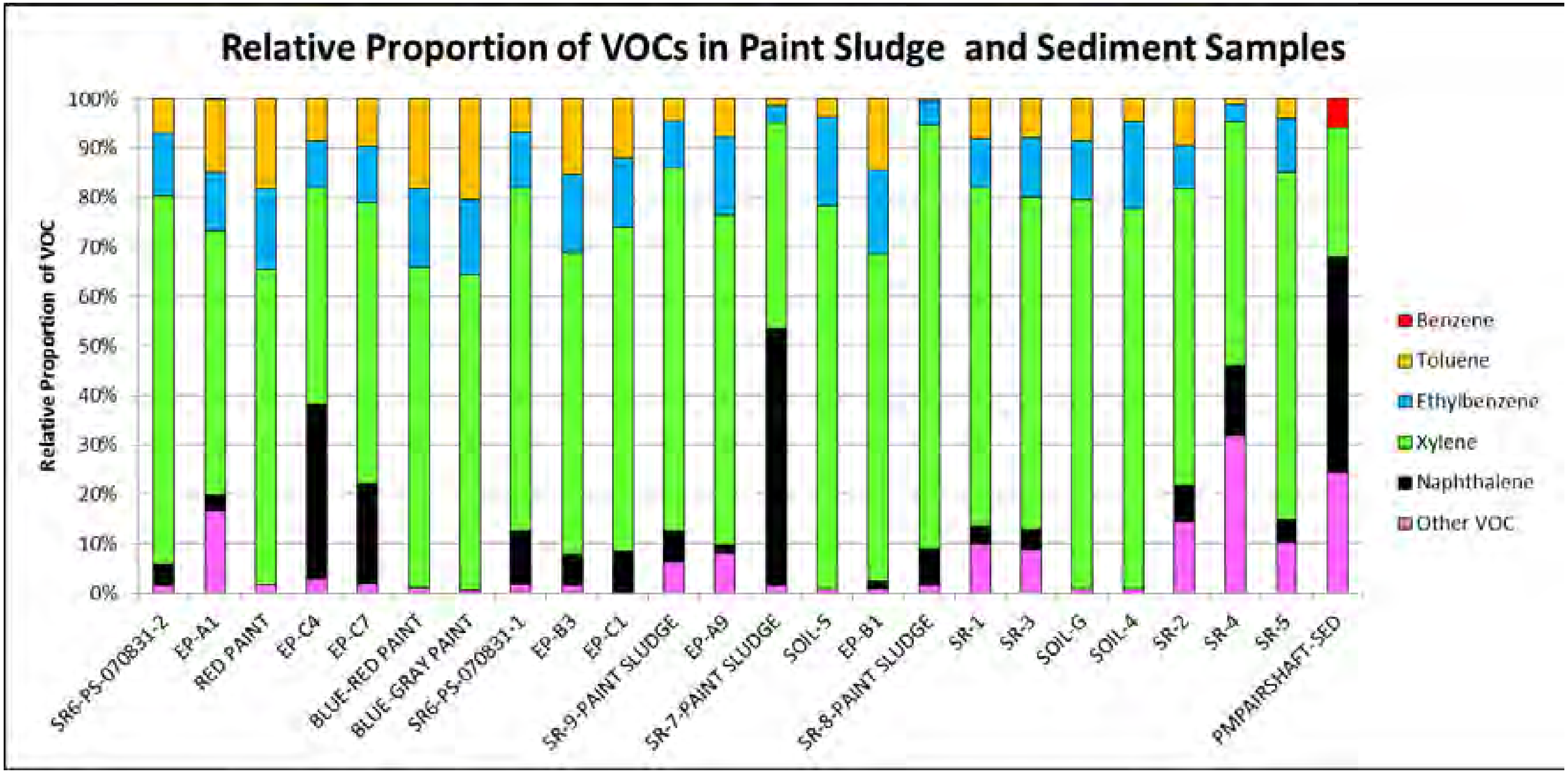
Forensic Analysis Metals

Paint Sludge is Not Part of the Sediment Mix



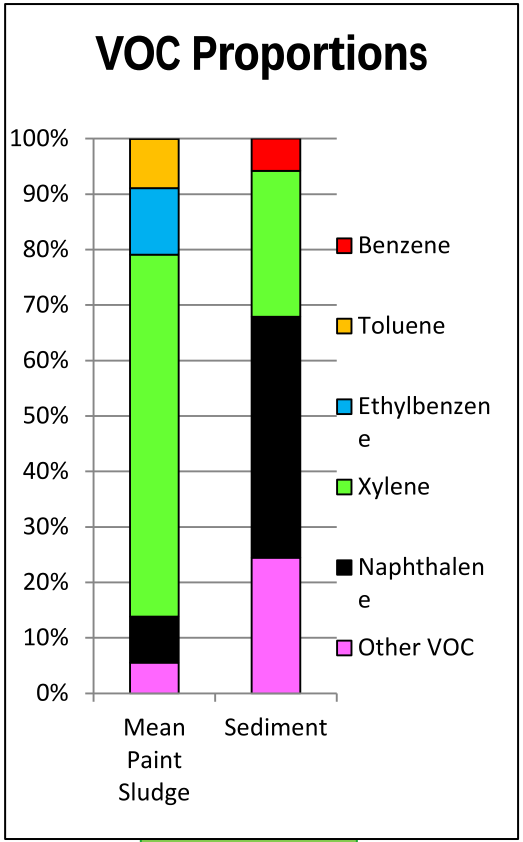
- Multivariate Cluster Analysis (MCA) is a statistical tool used to group samples based on the overall similarity in composition based on relationships between target metals within the samples
- Dendogram from Cluster Analysis showing air shaft sample on the far right (pink), clearly separated from the other paint sludge samples

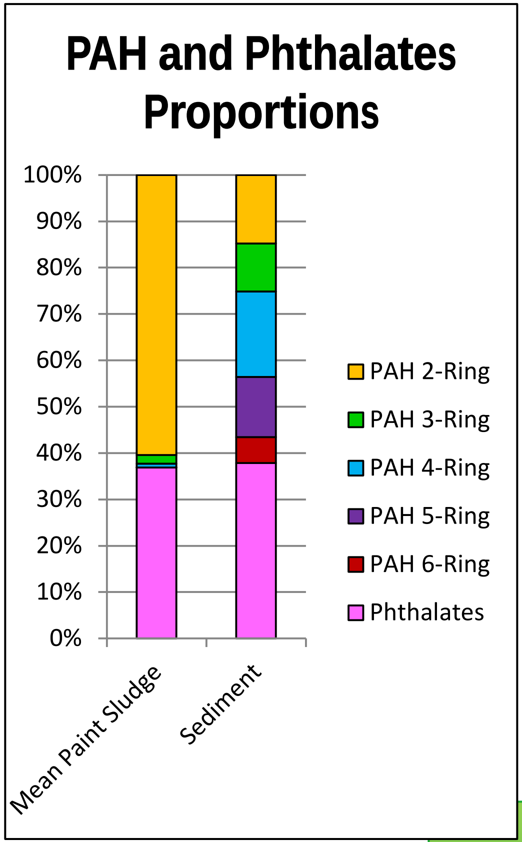
Forensic Analysis VOCs
Sediment Sample is Not Paint Sludge

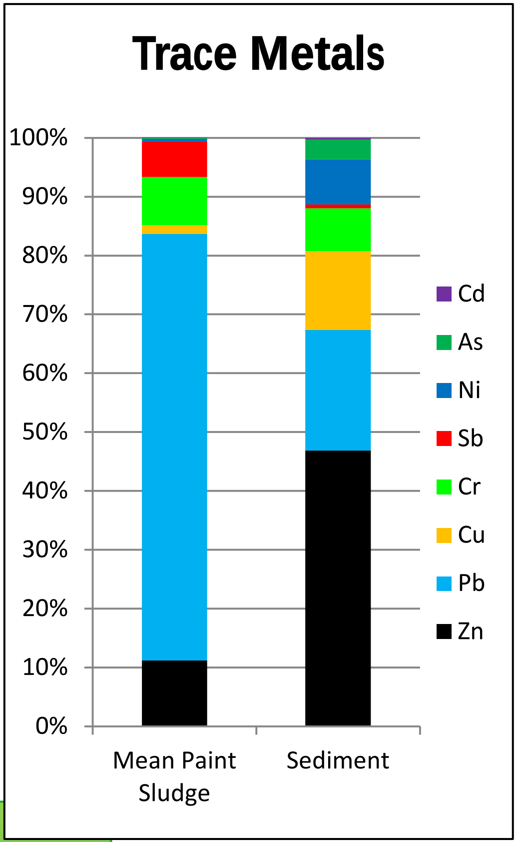


- Distribution of VOCs in sediment sample is not consistent with the VOC distribution in paint sludge samples

Forensic Analysis Summary







Benzene in paint sludge (0.3% of total VOCs) cannot account for benzene in sediment (5% of total VOCs)

Sediment does not contain paint sludge

CSM Forensic Analysis Summary

Based on three lines of evidence, sediment sample is not paint sludge

- ü PAHs
- ü Metals
- ü VOCs

CSM Summary

- **Based on forensics**
  - Sediment is not paint sludge
- **Based on timeline**
  - Pumps were removed from mines in 1960
    (A. Getz, NJ Mine Safety Bureau, 1965)
  - Mine filled within 7 years of abandonment
    (A. Getz, NJ Mine Safety Bureau, 1965)
  - Waste disposal occurred in 1967 and 1971, after mine filled
- **Based on stratification**
  - Benzene is contained at the bottom of the air shaft
  - There is no mechanism that could drive benzene down to the bottom of the air shaft after the mine was flooded.

Evaluation of Pilot Test

- **Current system is containing and naturally degrading benzene**
  - It is protective
  - Stratification of flooded mine works is common
  - Now that works are flooded, stability of stratification is expected for long term
- **Thermocline is technically defensible**
  - Founded in Limnology and mining
  - Flow meter data cannot be relied upon to assess flow in air shaft

Evaluation of Pilot Test

Performing pilot test has several risks

- Implementation of pilot could upset stratification that is containing and degrading benzene
  - Could enable transport of benzene to shallow system
  - Could change flux conditions in deep zone (i.e. change partitioning rate from sediment into water)
- Indicates/implies that current conditions are not protective

Historical Pumping from PM Air Shaft–

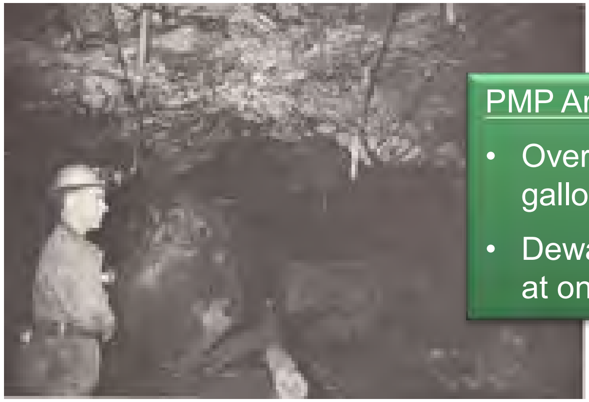
October 1980:

- Ringwood Fire Department pumped 420,000 gallons from air shaft over several days
  - Installed pipes to bottom of shaft (to facilitate lowering pumps)
  - Pumping occurred at base of shaft

- Water sample from 225 feet bgs revealed presence of 19 ug/l benzene
  - When the sample was collected is unclear (i.e. at the start, middle or end of pumping event)

Provides insight on possible outcome of proposed pilot test

- Pilot study will not resolve questions on source area



PMP Area facts:

- Over 213,000,000 gallons of capacity
- Dewatered by pumping at only 50 gpm

Images taken from *Vanishing Ironworks of the Ramapos*, James M. Ransom Published by Rutgers University. 1966

Evaluation of Pilot Test

What will EPA's recommended quiescent pumping or aeration do?

- It will upset stratification
- It will introduce multiple variables
- Would require protracted efforts to make pilot work
- Would require **long-term operations** and monitoring to demonstrate if pilot program can be stable

If the pilot test does not work, we cannot determine why it failed

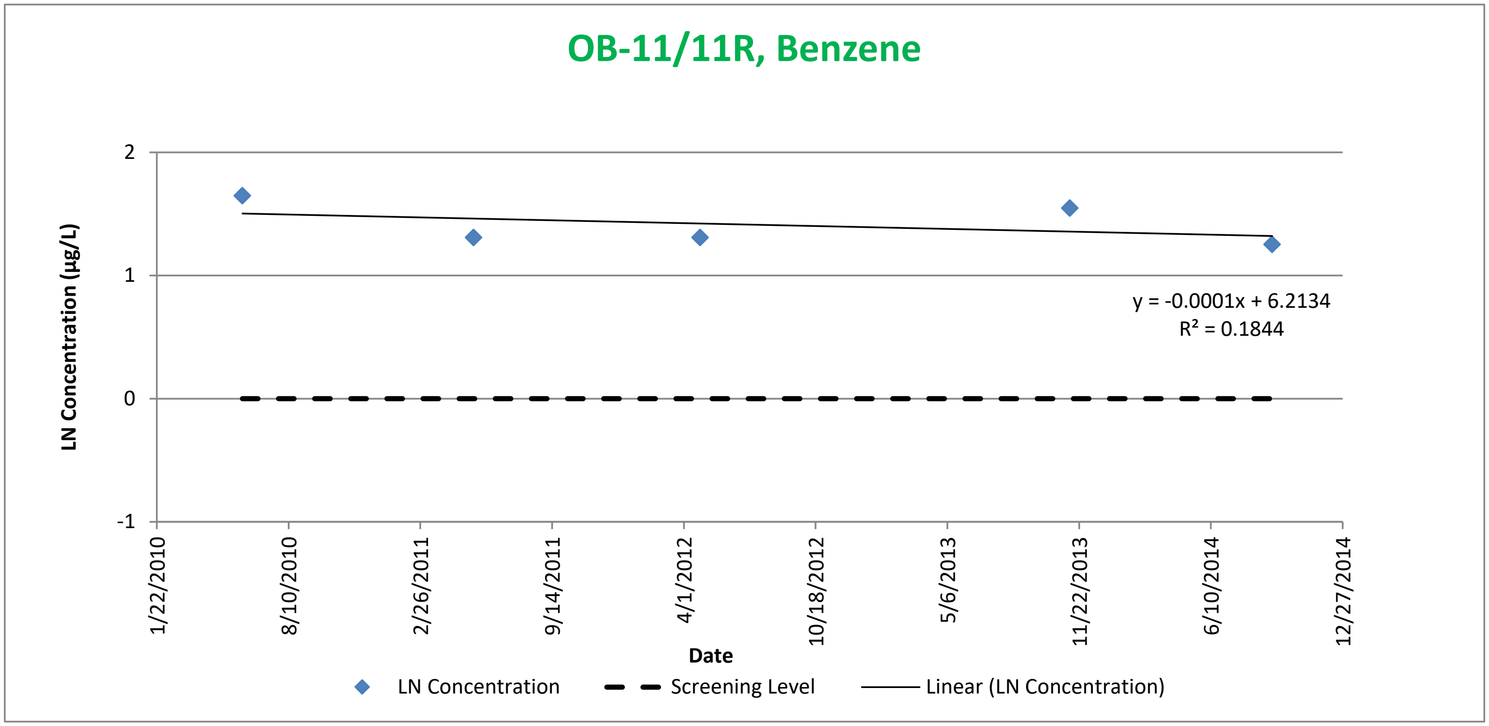
Pilot Test will not determine the source of benzene, and risks disrupting the stratified conditions that contain and degrade benzene

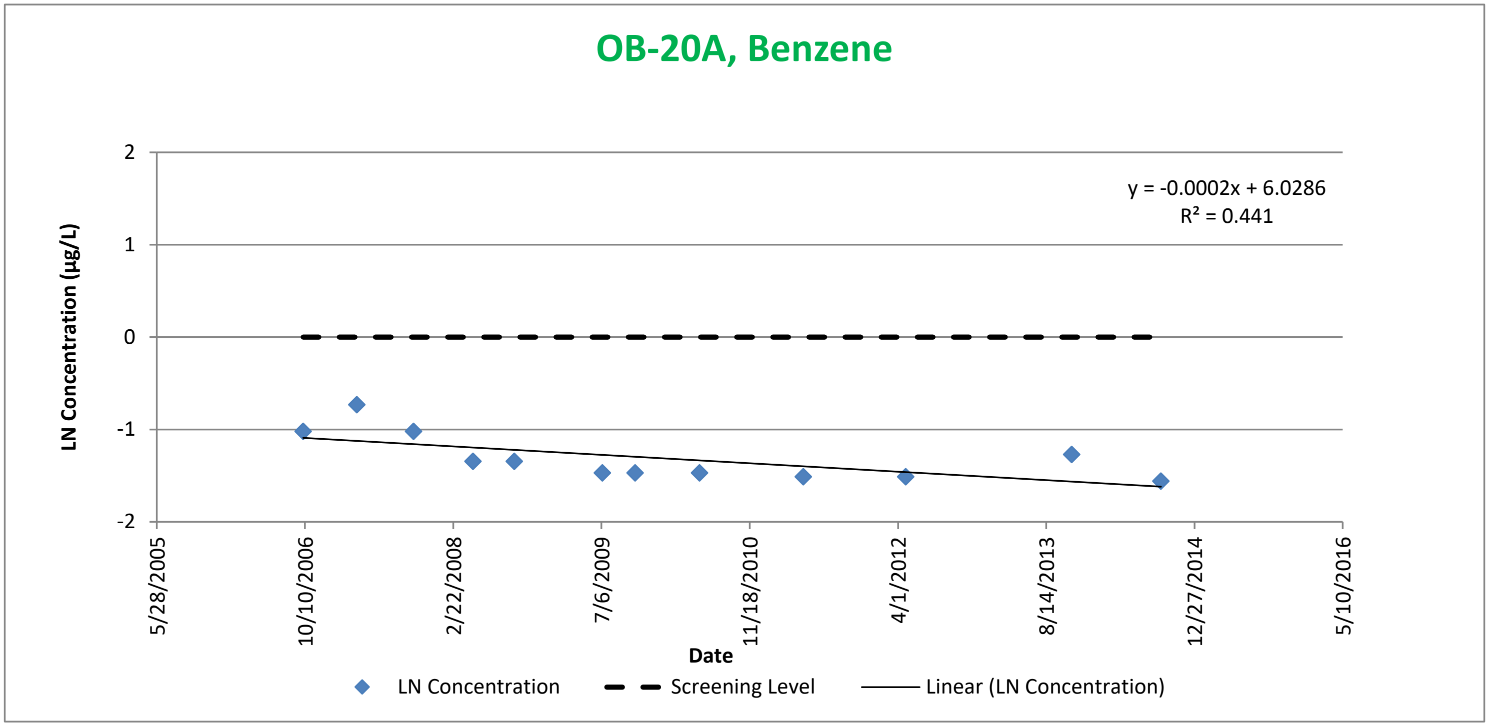
Appendix J
Summary of Statistical Analysis of Groundwater Analytical Data
Supplemental Site Related Groundwater Remedial Investigation
Ringwood Mines/Landfill Site, Ringwood

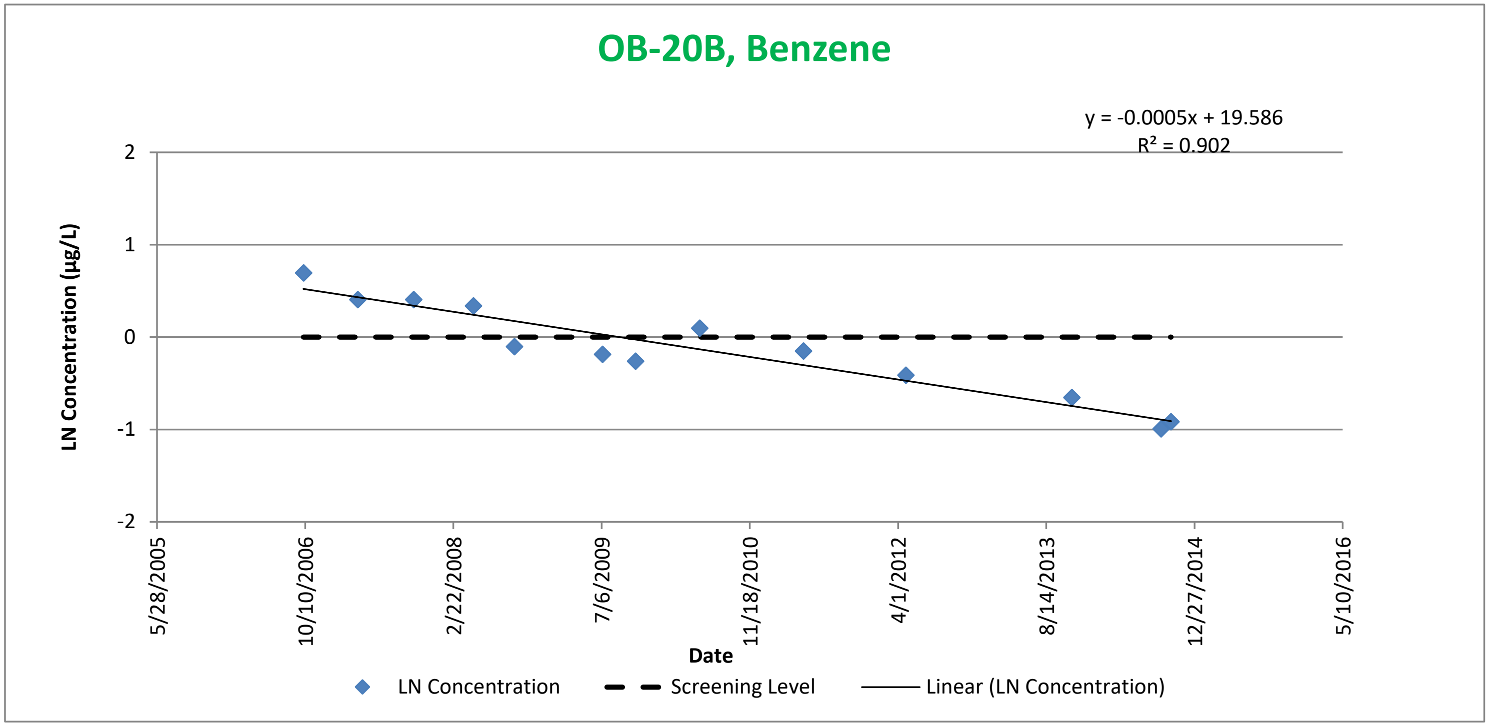
Constituent	Monitoring Location	Screening Level (µg/L)[1]	Data Range						Linear Regression Analysis					
			Minimum Concentration (µg/L)	Maximum Concentration (µg/L)	Concentration Measured Most Recently (µg/L)	% of Data Above Laboratory Reporting Limit	Start Date	End Date	Coefficient of Determination, R-squared[2]	p-value of Correlation (Significance of Slope)	Attenuation Half-life (days)	Trend Direction	Significance of Trend[2]	Projected Year to Screening Level
Benzene	OB-11/11R	1.0	3.50	5.2	3.5	100	6/1/2010	9/11/2014	0.18	0.47	5,934	Decreasing	NS	
Benzene	OB-20A	1.0	0.21	0.48	0.21	50	10/4/2006	9/5/2014	0.44	0.02	3,795	Decreasing	Significant	BSL
Benzene	OB-20B	1.0	0.37	2.0	0.40	100	10/4/2006	10/9/2014	0.90	0.00	1,417	Decreasing	Significant	BSL since 5/2011
Benzene	OB-27	1.0	2.60	6.5	2.6	100	6/1/2010	9/10/2014	0.87	0.02	1,216	Decreasing	Significant	2019
Benzene	RW-6A	1.0	1.30	15.0	6.8	100	10/16/2007	10/9/2014	0.25	0.15	--	Increasing	NS	
Benzene	RW-6	1.0	0.74	15.7	15.70	100	5/11/2006	10/9/2014	0.01	0.79	--	No Trend	NS	
Benzene	SC-01	1.0	0.53	1.6	1.6	100	4/11/2007	10/9/2014	0.06	0.46	--	No Trend	NS	Maximum concentration 1.6 ug/L
Benzene	PM Air Shaft 180	1.0	0.22	26.4	6.60	56	5/7/2008	9/16/2014	0.004	0.87	--	No Trend	NS	BSL 5 of 9 monitoring events
Benzene	PM Air Shat 230	1.0	0.22	33.2	32.9	89	5/7/2008	9/17/2014	0.03	0.63	--	No Trend	NS	

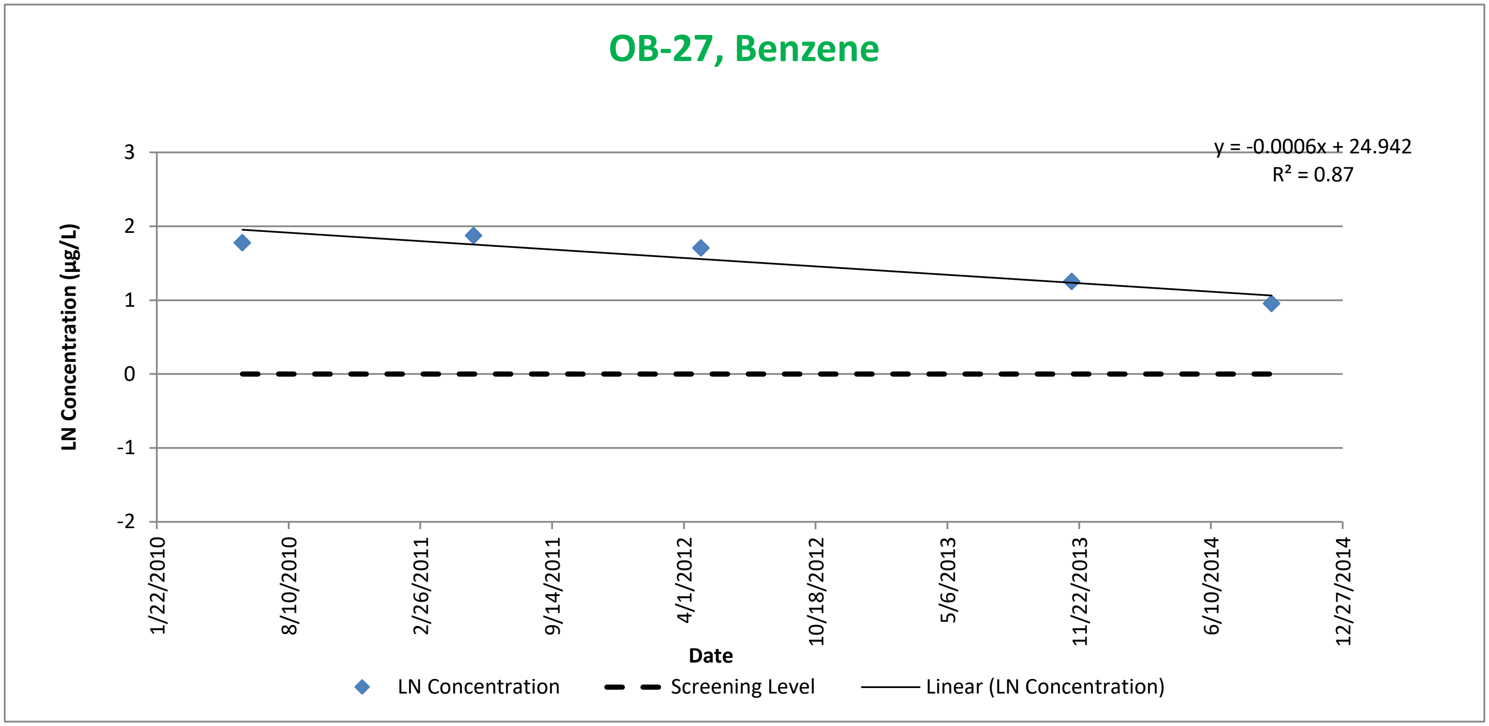
Constituent	Monitoring Location	Screening Level (µg/L)[1]	Mann-Kendall Analysis				Sen's Slope Analysis					
			S-statistic	p-value of Trend	Trend Direction	Significance of Trend[2]	Lower 90% Confidence Level of Slope	Slope	Upper 90% Confidence Level of Slope	Attenuation Half-life (days)	Trend Direction	Significance of Trend[2]
Benzene	OB-11/11R	1.0	-5	0.18	Decreasing	NS	-0.001	-0.0001	0.0001	6930	Decreasing	NS
Benzene	OB-20A	1.0	-44	0.001	Decreasing	Significant	-0.0003	-0.0002	-0.0001	3465	Decreasing	Significant
Benzene	OB-20B	1.0	-65	<0.001	Decreasing	Significant	-0.0006	-0.0005	-0.0004	1386	Decreasing	Significant
Benzene	OB-27	1.0	-8	0.04	Decreasing	Significant	-0.0009	-0.0006	-0.0003	1155	Decreasing	Significant
Benzene	RW-6A	1.0	7	0.3	Increasing	NS	-0.0007	0.0001	0.0008	--	Increasing	NS
Benzene	RW-6	1.0	-35	0.05	Decreasing	Significant	-0.0005	-0.0002	-0.0001	3465	Decreasing	Significant
Benzene	SC-01	1.0	11	0.22	Increasing	NS	-0.0003	0	0.0003	--	Increasing	NS
Benzene	PM Air Shaft 180	1.0	-8	0.24	Decreasing	NS	-0.0072	-0.0002	0.0019	3465	Decreasing	NS
Benzene	PM Air Shaft 230	1.0	0	0.54	NT	NS	-0.0003	0	-0.0001	--	NT	NS

Notes, Abbreviations and Assumptions:
BSL = Below Screening Level
µg/L = micrograms per liter
NS = not significant
[1] New Jersey Department of Environmental Protection Groundwater Quality Standard
[2] Statistically significant trend defined as having p-value ≤ 0.10.
-- = attenuation half life not calculated due to no trend


OB-11/11R, Benzene
LN Concentration (µg/L)
2
1
0
-1
y = -0.0001x + 6.2134
R² = 0.1844
1/22/2010
8/10/2010
2/26/2011
9/14/2011
4/1/2012
10/18/2012
5/6/2013
11/22/2013
6/10/2014
12/27/2014
Date
LN Concentration
Screening Level
Linear (LN Concentration)


OB-20A, Benzene
y = -0.0002x + 6.0286
R² = 0.441
LN Concentration (µg/L)
2
1
0
-1
-2
5/28/2005
10/10/2006
2/22/2008
7/6/2009
11/18/2010
4/1/2012
8/14/2013
12/27/2014
5/10/2016
Date
LN Concentration
Screening Level
Linear (LN Concentration)


OB-20B, Benzene
y = -0.0005x + 19.586
R² = 0.902
LN Concentration (µg/L)
2
1
0
-1
-2
5/28/2005
10/10/2006
2/22/2008
7/6/2009
11/18/2010
4/1/2012
8/14/2013
12/27/2014
5/10/2016
Date
LN Concentration
Screening Level
Linear (LN Concentration)


OB-27, Benzene
y = -0.0006x + 24.942
R² = 0.87
LN Concentration (µg/L)
3
2
1
0
-1
-2
1/22/2010
8/10/2010
2/26/2011
9/14/2011
4/1/2012
10/18/2012
5/6/2013
11/22/2013
6/10/2014
12/27/2014
Date
LN Concentration
Screening Level
Linear (LN Concentration)

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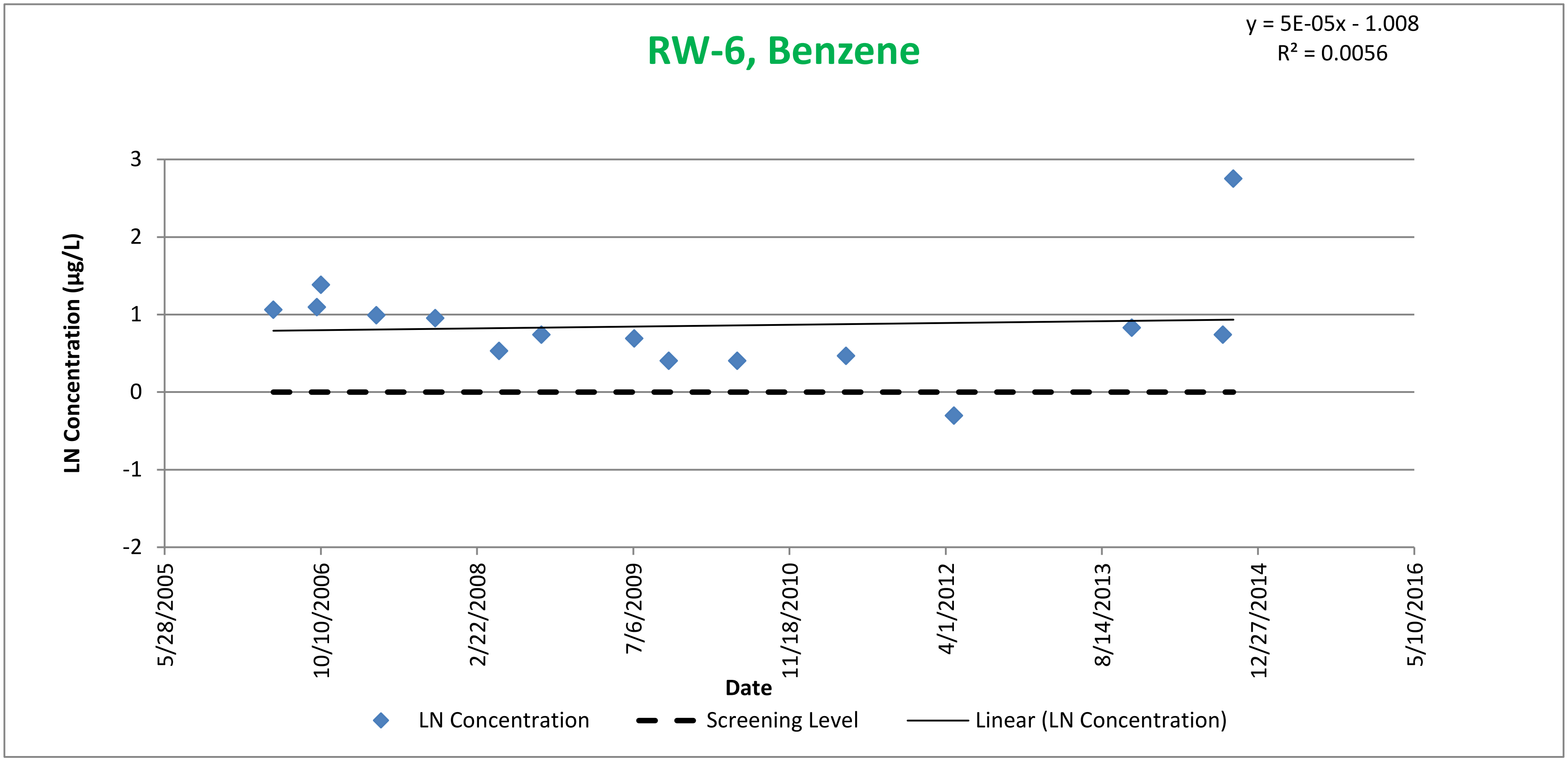

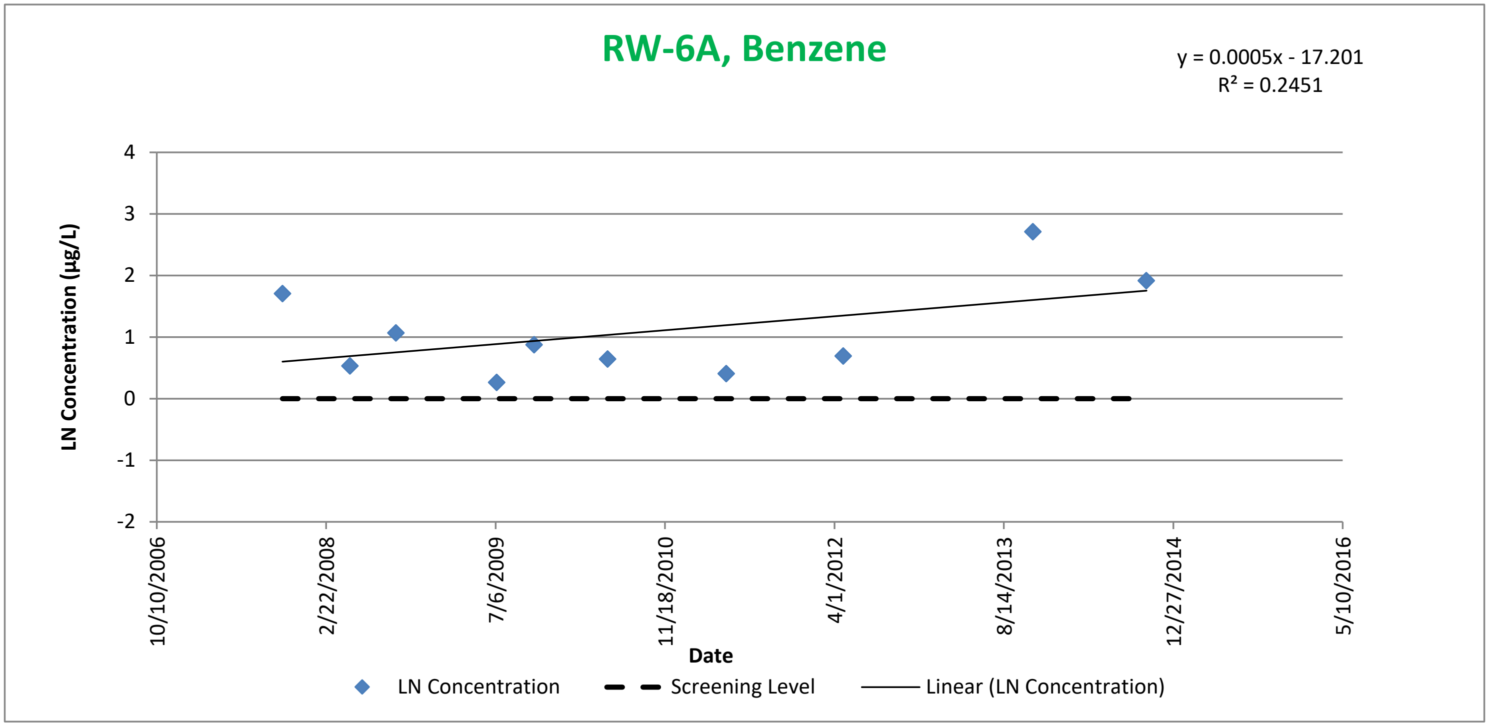
RW-6A, Benzene
y = 0.0005x - 17.201
R² = 0.2451
LN Concentration (µg/L)
4
3
2
1
0
-1
-2
10/10/2006
2/22/2008
7/6/2009
11/18/2010
4/1/2012
8/14/2013
12/27/2014
5/10/2016
Date
LN Concentration
Screening Level
Linear (LN Concentration)

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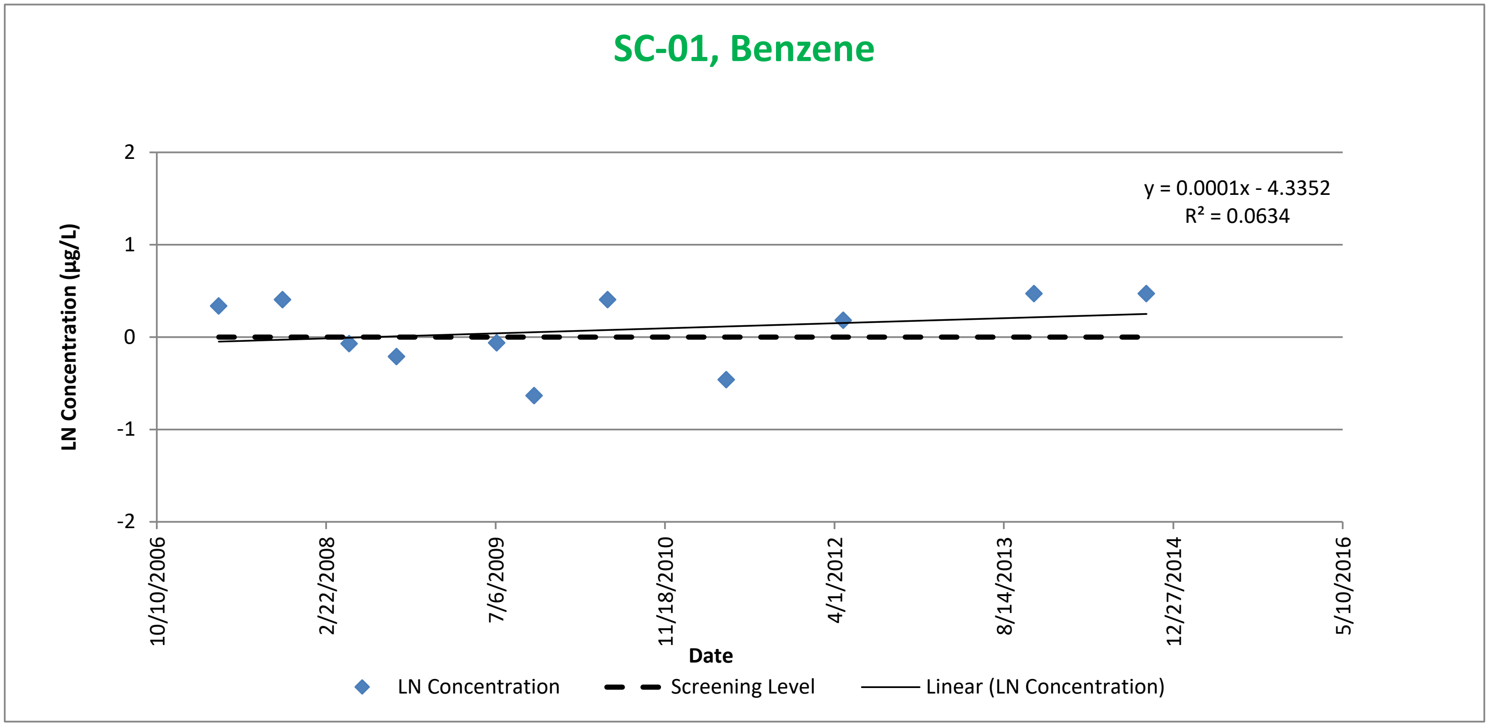

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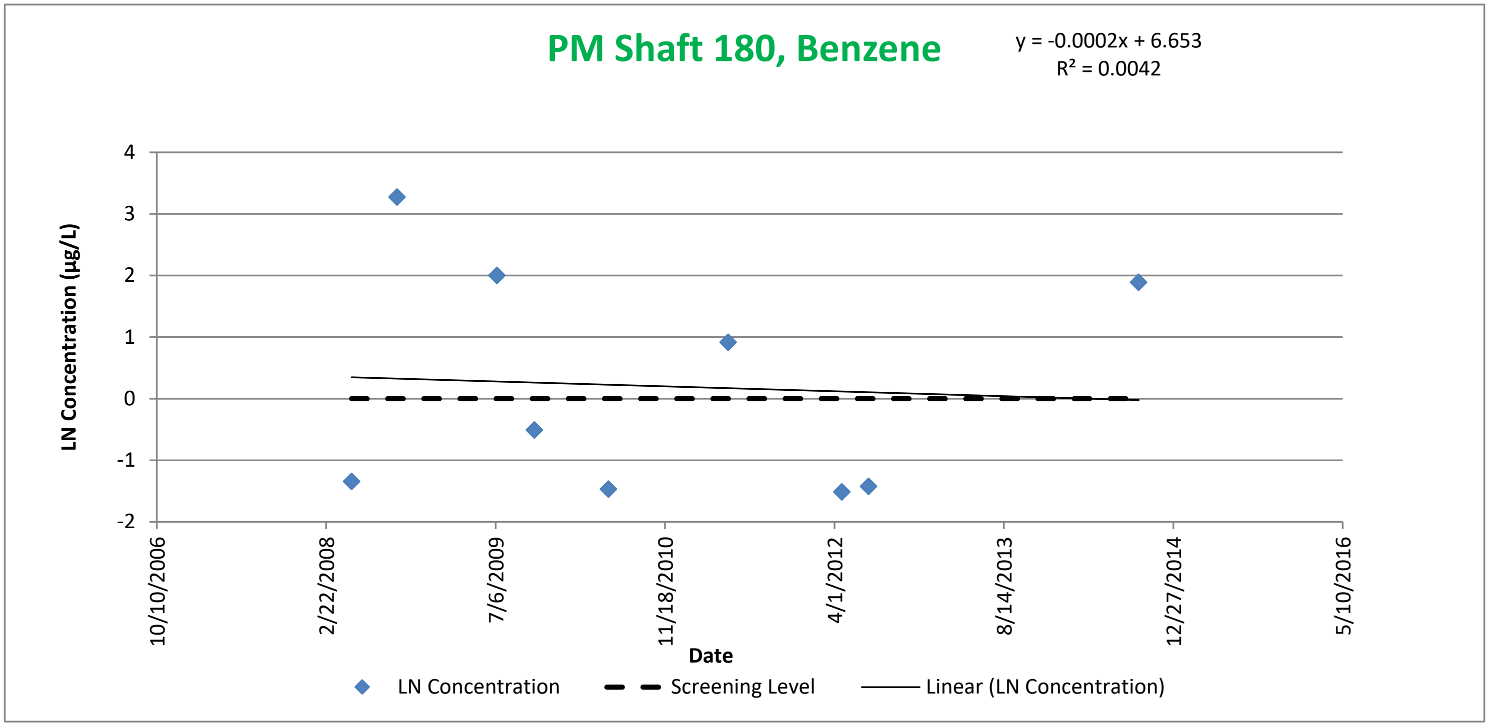

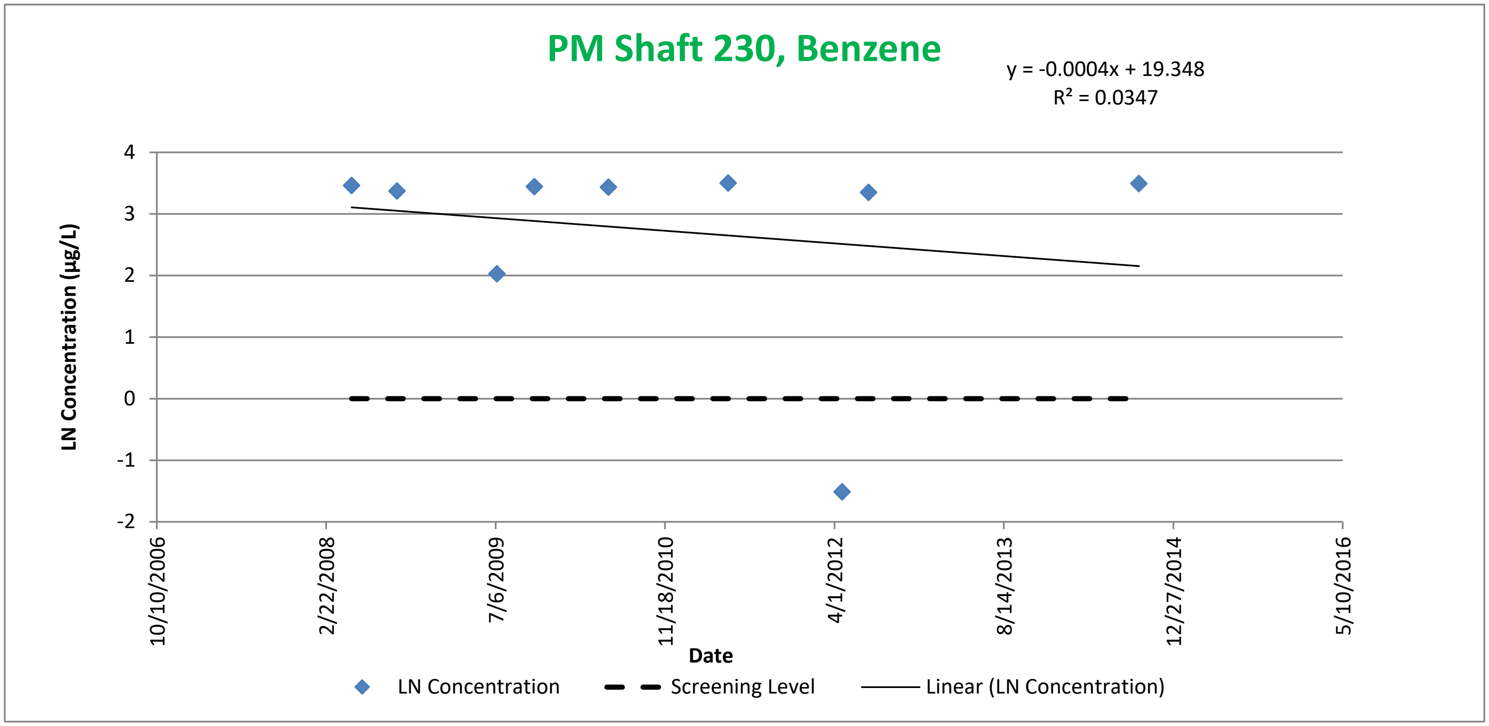
PM Shaft 230, Benzene
y = -0.0004x + 19.348
R² = 0.0347
4
3
2
1
0
-1
-2
LN Concentration (µg/L)
10/10/2006
2/22/2008
7/6/2009
11/18/2010
4/1/2012
8/14/2013
12/27/2014
5/10/2016
Date
LN Concentration
Screening Level
Linear (LN Concentration)

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SITE LOGIC Report

Stable Isotope Probing (SIP) Study

Contact: Jeremy Cuccuini

Address: ARCADIS
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Cranbury, NJ 08512

Phone: 609.860.0590

Email: Jeremy.cuccuini@arcadis-us.com

MI Identifier: **040JG**

Report Date: 08/31/2012

Project: Ringwood Mines/Landfill Site, Project # NJ000604.0035.0034

Comments:

Executive Summary

A Bio-Trap® Stable Isotope Probing (SIP) study was performed to investigate whether benzene biodegradation is occurring under existing site conditions. Bio-Trap® samplers were baited with ^{13}C labeled benzene and deployed in monitoring wells OB-27, OB-11R, RW-6, OB-20A, OB-20B, RW-6A, and SC-1. Following a 33 day deployment period, all Bio-Traps were recovered for quantification of ^{13}C incorporation into biomass and dissolved inorganic carbon (DIC). A complete summary of the results is provided in Tables 1 and 2.

- All monitoring wells demonstrated biodegradation of benzene under existing site conditions.
  - Despite low to moderate total biomass and low expression of phenol hydroxylase (PHE), incorporation of ^{13}C into biomass occurred at all monitoring wells.
  - Monitoring wells OB-27, RW-6, OB-20B, RW-6A, and SC-1 exhibited low incorporation of ^{13}C into biomass.
  - Monitoring well OB-11R exhibited moderate incorporation of ^{13}C into biomass.
  - Monitoring well OB-20A demonstrated a high level of ^{13}C incorporation into biomass.
    - ^{13}C enriched biomass was an order of magnitude higher than in wells RW-6A and SC-1 and two orders of magnitude higher than in the remaining wells.
- Average PLFA DEL values were high in well OB-20A (5184‰), moderate in well OB-11R (143‰), and low in the remaining wells (< 59‰).
- All wells demonstrated a low amount of ^{13}C incorporation into respiration processes (mineralization).

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Overview of Approach

Stable Isotope Probing (SIP)

Stable isotope probing (SIP) is an innovative method to track the environmental fate of a "labeled" contaminant of concern to unambiguously demonstrate biodegradation. Two stable carbon isotopes exist in nature – carbon 12 (^{12}C) which accounts for 99% of carbon and carbon 13 (^{13}C) which is considerably less abundant (~1%). With the SIP method, the Bio-Trap® sampler is baited with a specially synthesized form of the contaminant containing ^{13}C labeled carbon. Since ^{13}C is rare, the labeled compound can be readily differentiated from the contaminants present at the site. Following deployment, the Bio-Trap® is recovered and three approaches are used to conclusively demonstrate biodegradation of the contaminant of concern.

- The loss of the labeled compound provides an estimate of the degradation rate (% loss of ^{13}C).
- Quantification of ^{13}C enriched phospholipid fatty acids (PLFA) indicates incorporation into microbial biomass.
- Quantification of ^{13}C enriched dissolved inorganic carbon (DIC) indicates contaminant mineralization.

Phospholipid Fatty Acids (PLFA): PLFA are a primary component of the membrane of all living cells including bacteria. PLFA decomposes rapidly upon cell death (1, 2), so the total amount of PLFA present in a sample is indicative of the viable biomass. When combined with stable isotope probing (SIP), incorporation of ^{13}C into PLFA is a conclusive indicator of biodegradation.

Some organisms produce "signature" types of PLFA allowing quantification of important microbial functional groups (e.g. iron reducers, sulfate reducers, or fermenters). The relative proportions of the groups of PLFA provide a "fingerprint" of the microbial community. In addition, *Proteobacteria* modify specific PLFA during periods of slow growth or in response to environmental stress providing an index of their health and metabolic activity.

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Results

Table 1. Summary of the results obtained from the Bio-Trap® Units. Interpretation guidelines and definitions are found later in the document.

Sample Name	OB-27	OB-11R	RW-6	OB-20A
mRNA (gene copies/bead)				
Phenol Hydroxylase (PHE)	<5.00E+01	<5.00E+01	<5.00E+01	<5.00E+01
Contaminant Loss (mg/bd)				
Benzene Pre-deployment	138 ± 9	138 ± 9	138 ± 9	138 ± 9
Benzene Post-deployment	102 ± 5	103 ± 5	100 ± 6	15 ± 1
Biomass & ^{13}C Incorporation				
Total Biomass (Cells/bd)	5.41E+04	4.20E+04	5.79E+05	4.90E+05
^{13}C Enriched Biomass (Cells/bd)	1.33E+02	1.49E+02	7.09E+02	4.58E+04
Average PLFA Del (‰)	38	143	19	5184
Maximum PLFA Del (‰)	45	242	49	11168
^{13}C Mineralization				
DIC Del (‰)	9.3	13.6	7.6	-5.7
% 13C	1.10%	1.10%	1.10%	1.10%
Community Structure (% total PLFA)				
Firmicutes (TerBrSats)	0.0	0.0	1.4	3.7
Proteobacteria (Monos)	81.1	83.4	84.1	73.7
Anaerobic metal reducers (BrMonos)	0.0	0.0	0.0	0.0
Actinomycetes (MidBrSats)	0.0	0.0	0.6	0.0
General (Nsats)	14.1	12.4	8.3	21.5
Eukaryotes (Polyenoics)	4.8	4.2	5.6	1.1
Physiological Status (Proteobacteria only)				
Slowed Growth	0.10	0.09	0.07	2.98
Decreased Permeability	0.00	0.00	0.28	0.19

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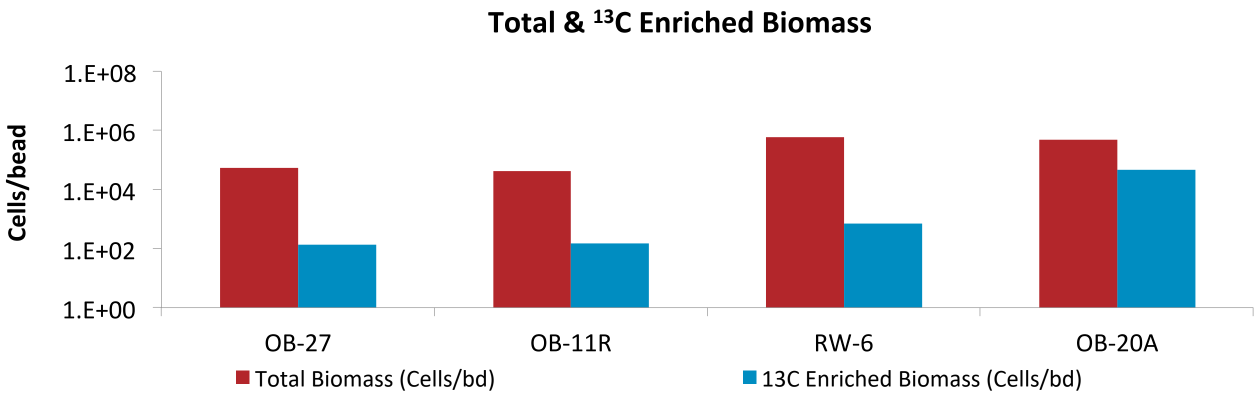

Figure 1. Biomass content is presented as a cell equivalent based on the total amount of phospholipid fatty acids (PLFA) extracted from a given sample. Total biomass is calculated based upon PLFA attributed to bacterial and eukaryotic biomass (associated with higher organisms).

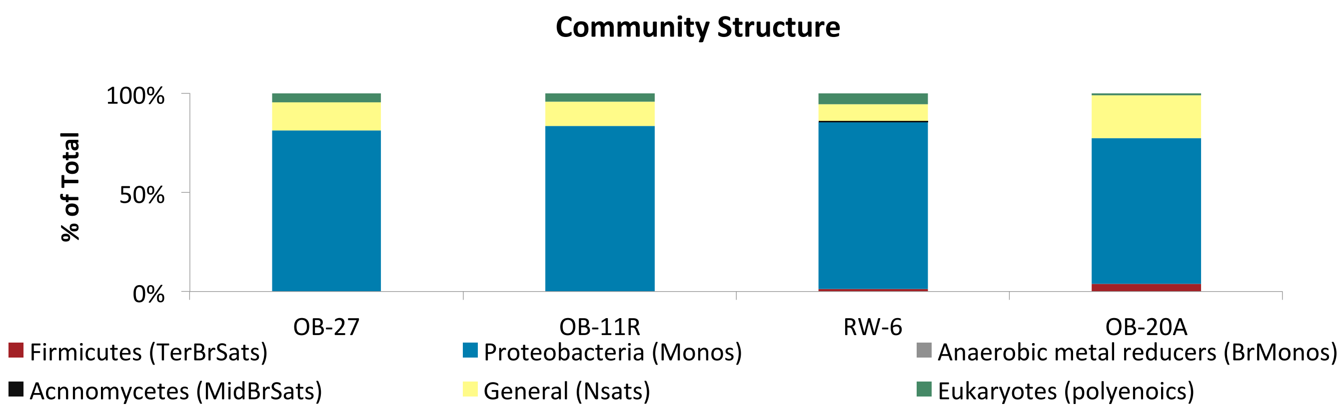

Figure 2. Relative percentages of total PLFA structural groups in the samples analyzed. Structural groups are assigned according to PLFA chemical structure, which is related to fatty acid biosynthesis. See the table in the interpretation section for detailed descriptions of the structural groups.

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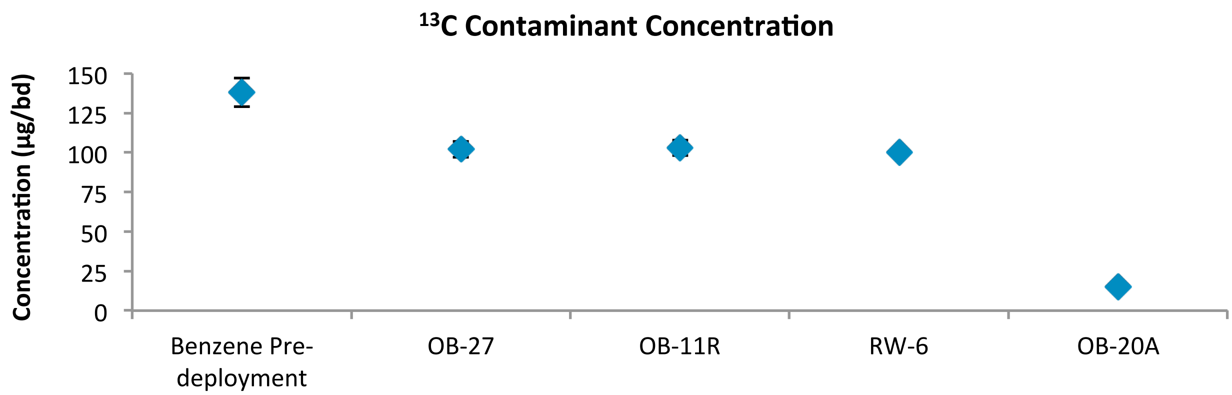

Figure 3. Comparison of Pre-deployment concentrations loaded on Bio-Sep beads to the concentrations detected after incubation

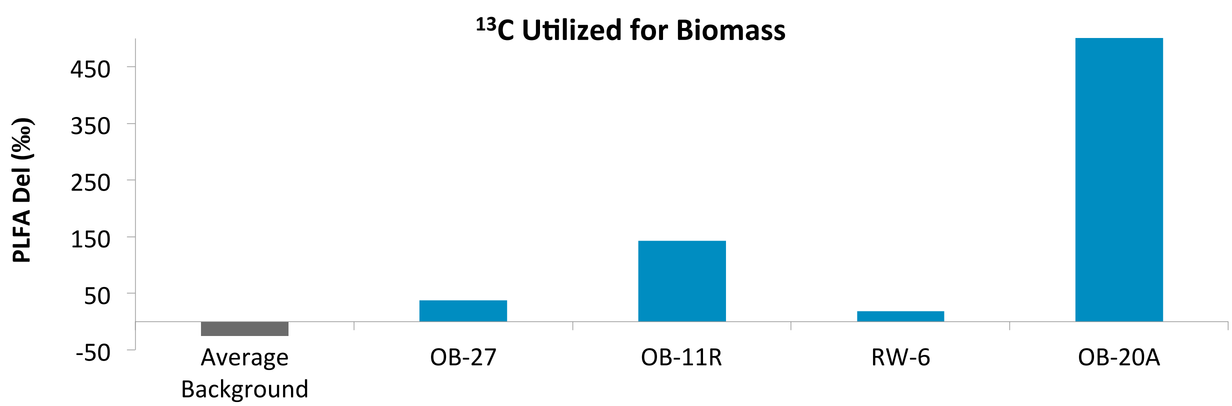

Figure 4. Comparison of the average Del value obtained from PLFA biomarkers from each Bio-Trap® unit to the average background Del observed in samples not exposed to ^{13}C enriched compounds.

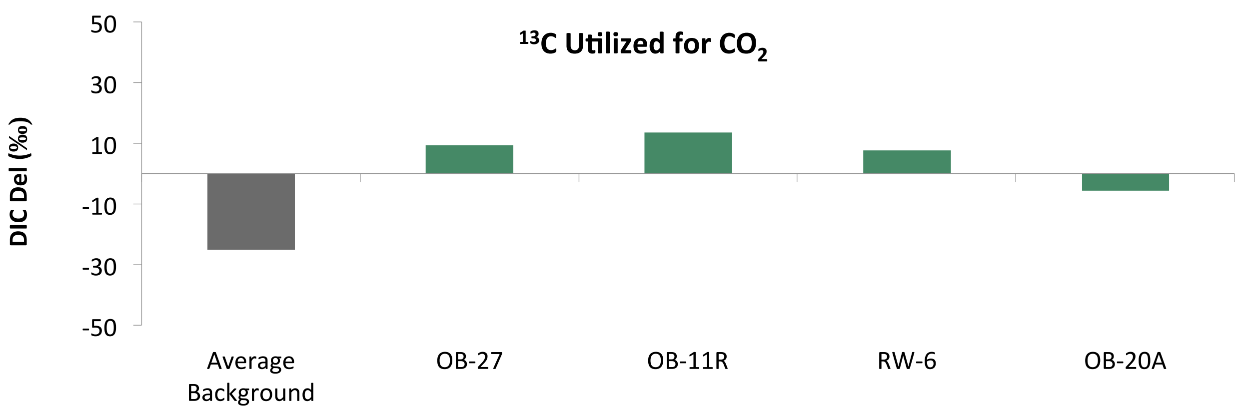

Figure 5. Comparison of the Del value obtained from DIC from each Bio-Trap® unit to the average background Del observed in samples not exposed to ^{13}C enriched compounds.

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Table 2. Summary of the results obtained from the Bio-Trap® Units. Interpretation guidelines and definitions are found later in the document.

Sample Name	OB-20B	RW-6A	SC-1
mRNA (gene copies/bead)			
Phenol Hydroxylase (PHE)	<5.00E+01	<5.00E+01	<5.00E+01
Contaminant Loss (mg/bd)			
Benzene Pre-deployment	138 ± 9	138 ± 9	138 ± 9
Benzene Post-deployment	103 ± 6	103 ± 7	94 ± 3
Biomass & ^{13}C Incorporation			
Total Biomass (Cells/bd)	9.37E+04	9.57E+05	1.47E+06
^{13}C Enriched Biomass (Cells/bd)	5.53E+02	2.04E+03	1.44E+03
Average PLFA Del (‰)	59	21	10
Maximum PLFA Del (‰)	135	51	23
^{13}C Mineralization			
DIC Del (‰)	2.0	-2.6	-2.2
% 13C	1.10%	1.10%	1.10%
Community Structure (% total PLFA)			
Firmicutes (TerBrSats)	2.6	2.4	2.6
Proteobacteria (Monos)	80.6	80.1	81.3
Anaerobic metal reducers (BrMonos)	0.0	0.0	0.1
Actinomycetes (MidBrSats)	0.0	0.7	1.1
General (Nsats)	14.8	11.9	11.6
Eukaryotes (Polyenoics)	2.1	5.0	3.3
Physiological Status (Proteobacteria only)			
Slowed Growth	0.09	0.01	0.01
Decreased Permeability	0.30	0.09	0.09

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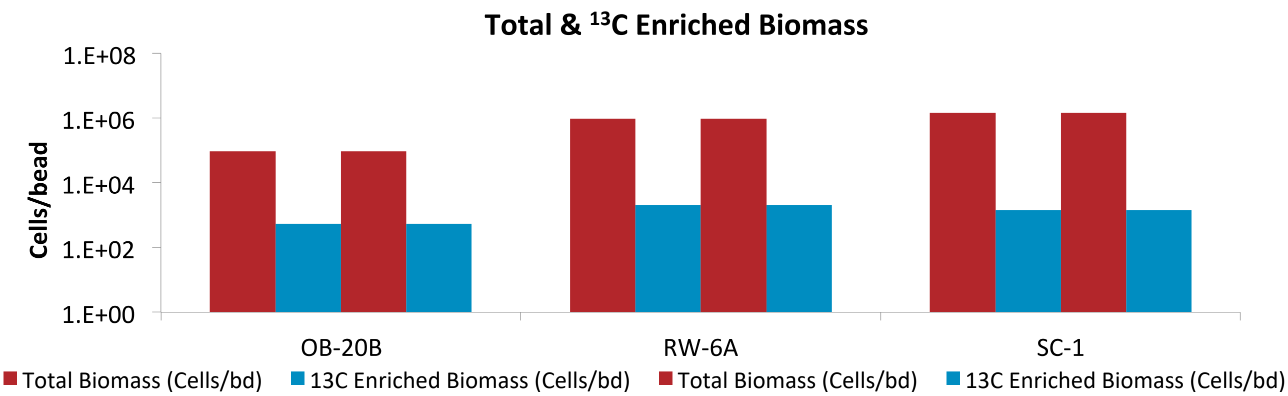

Figure 6. Biomass content is presented as a cell equivalent based on the total amount of phospholipid fatty acids (PLFA) extracted from a given sample. Total biomass is calculated based upon PLFA attributed to bacterial and eukaryotic biomass (associated with higher organisms).

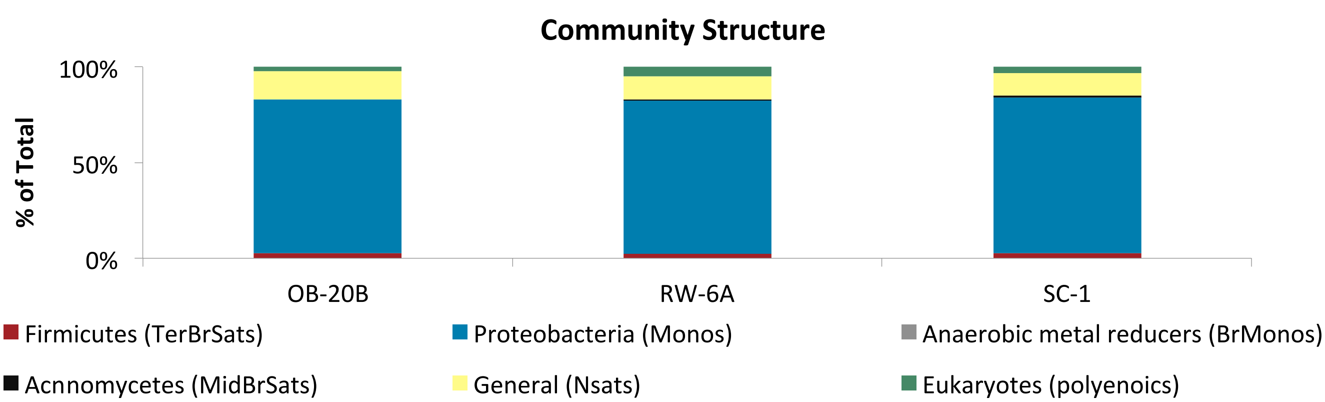

Figure 7. Relative percentages of total PLFA structural groups in the samples analyzed. Structural groups are assigned according to PLFA chemical structure, which is related to fatty acid biosynthesis. See the table in the interpretation section for detailed descriptions of the structural groups.

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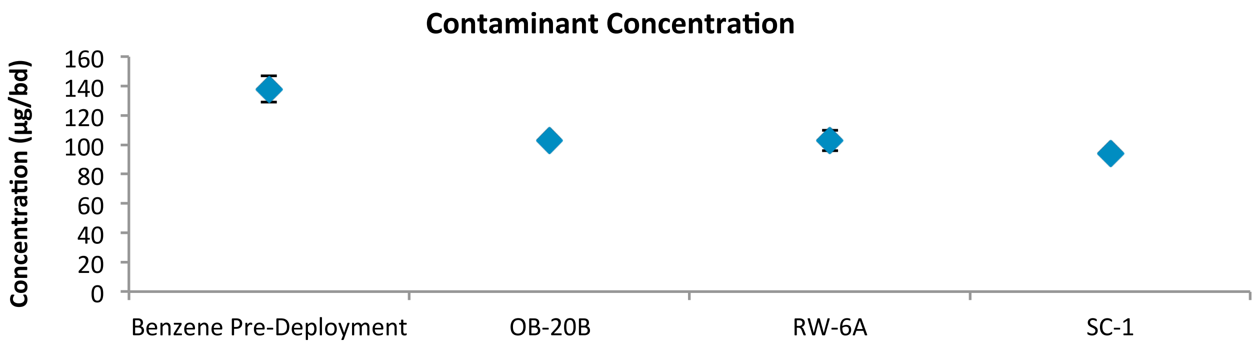

Figure 8. Comparison of Pre-deployment concentrations loaded on Bio-Sep beads to the concentrations detected after incubation

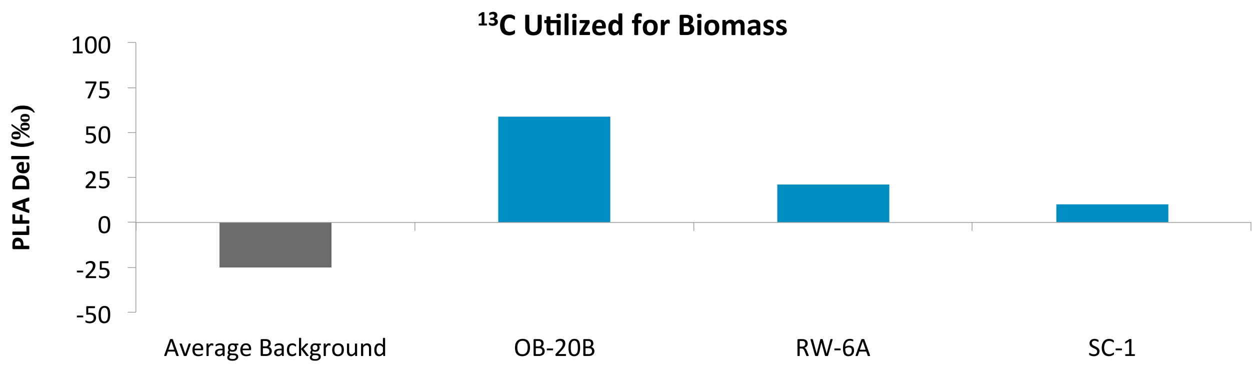

Figure 9. Comparison of the average Del value obtained from PLFA biomarkers from each Bio-Trap® unit to the average background Del observed in samples not exposed to ^{13}C enriched compounds.

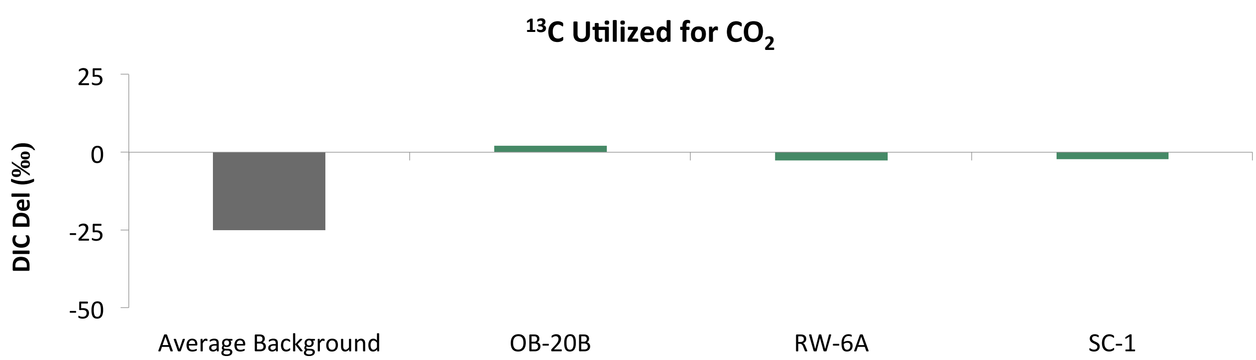

Figure 10. Comparison of the Del value obtained from DIC from each Bio-Trap® unit to the average background Del observed in samples not exposed to ^{13}C enriched compounds.

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Interpretation

Interpretation of the results of the SIP Bio-Trap® study must be performed with due consideration of site conditions, site activities, and the desired treatment mechanism. The following discussion describes interpretation of results in general terms and is meant to serve as a guide.

Contaminant Concentration: Bio-Traps® are baited with a ^{13}C labeled contaminant of concern and a pre-deployment concentration is determined prior to shipping. Following deployment, Bio-Traps® are recovered for analysis including measurement of the concentration of the ^{13}C labeled contaminant remaining.

Biomass Concentrations: PLFA analysis is one of the most reliable and accurate methods available for the determination of viable (live) biomass. Phospholipids break down rapidly upon cell death, so biomass calculations based on PLFA content do not include "fossil" lipids from dead cells. Total biomass (cells/bead) is calculated from total PLFA using a conversion factor of 20,000 cells/pmole of PLFA. When making comparisons between wells, treatments, or over time, differences of one order of magnitude or more are considered significant.

	Total Biomass	
Low	**Moderate**	**High**
10^3 to 10^4 cells	10^5 to 10^6 cells	10^7 to 10^8 cells

For SIP studies, the ^{13}C enriched PLFA is also determined to conclusively demonstrate contaminant biodegradation and quantify incorporation into biomass as a result of the ^{13}C being used for cellular growth. The % ^{13}C incorporation (^{13}C enriched biomass/total biomass) is also provided in the data summary table, but the value must be interpreted carefully especially when comparing wells or treatments. Typically, biodegradation of a contaminant of concern is performed by a small subset of the total microbial community. For Bio-Traps® with large total biomass, the % ^{13}C incorporation value could be low despite significant ^{13}C labeled biomass and loss of the compound. The % ^{13}C incorporation should be viewed in light of total biomass, percent loss, and dissolved inorganic carbon (DIC) results.

^{13}C enrichment data is often reported as a del value. The del value is the difference between the isotopic ratio ($^{13}C/^{12}C$) of the sample (R_x) and a standard (R_{std}) normalized to the isotopic ratio of the standard (R_{std}) and multiplied by 1,000 (units are parts per thousand, denoted ‰).

R_{std} is the naturally occurring isotopic ratio and is approximately 0.011180 (roughly 1% of naturally occurring carbon is ^{13}C). The isotopic ratio, R_x, of PLFA is typically less than the R_{std} under natural conditions, resulting in a del value between -20 and -30‰. For a SIP Bio-Trap® study, biodegradation and incorporation of the ^{13}C labeled compound into PLFA results in a larger $^{13}C/^{12}C$ ratio (R_x) and thus del values greater than under natural conditions. Typical PLFA del values are provided below.

	PLFA Del (‰)	
Low	**Moderate**	**High**
0 to 100	100 to 1,000	>1,000

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Dissolved Inorganic Carbon (DIC): Often, bacteria can utilize the ^{13}C labeled compound as both a carbon and energy source. The ^{13}C portion used as a carbon source for growth can be incorporated into PLFA as discussed above, while the ^{13}C used for energy is oxidized to $^{13}CO_2$ (mineralized).

^{13}C enriched CO_2 data is often reported as a del value as described above for PLFA. Under natural conditions, the R_x of CO_2 is approximately the same as R_{std} (0.01118 or about 1.1% ^{13}C). For an SIP Bio-Trap® study, mineralization of the ^{13}C labeled contaminant of concern would lead to a greater value of R_x (increased $^{13}CO_2$ production) and thus a positive del value. As with PLFA, del values between 0 and 100‰ are considered low, values between 100 and 1,000‰ are considered moderate, and values greater than 1,000‰ are considered high. Thus DIC %^{13}C are considered low if the value is less than 1.23%, moderate if between 1.23 and 2.24%, and high if greater than 2.24%.

Dissolved Inorganic Carbon (DIC) Del and %^{13}C		
Low	**Moderate**	**High**
0 to 100	100 to 1,000	>1,000
1.11 to 1.23%	1.23 to 2.24%	>2.24%

Community Structure (% total PLFA): Community structure data is presented as a percentage of PLFA structural groups normalized to the total PLFA biomass. The relative proportions of the PLFA structural groups provide a "fingerprint" of the types of microbial groups (e.g. anaerobes, sulfate reducers, etc.) present and therefore offer insight into the dominant metabolic processes occurring at the sample location. Thorough interpretation of the PLFA structural groups depends in part on an understanding of site conditions and the desired microbial biodegradation pathways. For example, an increase in mid chain branched saturated PLFA (MidBrSats), indicative of sulfate reducing bacteria (SRB) and *Actinomycetes*, may be desirable at a site where anaerobic BTEX biodegradation is the treatment mechanism, but would not be desirable for a corrective action promoting aerobic BTEX or MTBE biodegradation. The following table provides a brief summary of each PLFA structural group and its potential relevance to bioremediation.

Table 2. Description of PLFA structural groups.

PLFA Structural Group	General classification	Potential Relevance to Bioremediation Studies
Monoenoic (Monos)	Abundant in Proteobacteria (Gram negative bacteria), typically fast growing, utilize many carbon sources, and adapt quickly to a variety of environments.	Proteobacteria is one of the largest groups of bacteria and represents a wide variety of both aerobes and anaerobes. The majority of Hydrocarbon utilizing bacteria fall within the Proteobacteria
Terminally Branched Saturated (TerBrSats)	Characteristic of Firmicutes (Low G+C Gram-positive bacteria), and also found in Bacteriodes, and some Gram-negative bacteria (especially anaerobes).	Firmicutes are indicative of presence of anaerobic fermenting bacteria (mainly *Clostridia/Bacteriodes*-like), which produce the H_2 necessary for reductive dechlorination
Branched Monoenoic (BrMonos)	Found in the cell membranes of micro-aerophiles and anaerobes, such as sulfate- or iron-reducing bacteria	In contaminated environments high proportions are often associated with anaerobic sulfate and iron reducing bacteria
Mid-Chain Branched Saturated (MidBrSats)	Common in sulfate reducing bacteria and also Actinobacteria (High G+C Gram-positive bacteria).	In contaminated environments high proportions are often associated with anaerobic sulfate and iron reducing bacteria
Normal Saturated (Nsats)	Found in all organisms.	High proportions often indicate less diverse populations.
Polyenoic	Found in eukaryotes such as fungi, protozoa, algae, higher plants, and animals.	Eukaryotic scavengers will often rise up and prey on contaminant utilizing bacteria

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Physiological Status (*Proteobacteria*): Some *Proteobacteria* modify specific PLFA as a strategy to adapt to stressful environmental conditions (3, 4). For example, *cis* monounsaturated fatty acids may be modified to cyclopropyl fatty acids during periods of slowed growth or modified to *trans* monounsaturated fatty acids to decrease membrane permeability in response to environmental stress. The ratio of product to substrate fatty acid thus provides an index of their health and metabolic activity. In general, status ratios greater than 0.25 indicate a response to unfavorable environmental conditions.

Glossary

Del: A Del value is the difference between the isotopic ratio ($^{13}C/^{12}C$) of the sample (R_x) and a standard (R_{std}) normalized to the isotopic ratio of the standard (R_{std}) and multiplied by 1,000 (units are parts per thousand denoted ‰).

$$Del = (R_x - R_{std})/R_{std} \times 1000$$

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1. White, D.C., W.M. Davis, J.S. Nickels, J.D. King, and R.J. Bobbie. 1979. Determination of the sedimentary microbial biomass by extractable lipid phosphate. Oecologia 40:51-62.
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SITE LOGIC Report

Stable Isotope Probing (SIP) Study

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MI Identifier: 032JI

Report Date: 10/31/2012

Project: Ford Ringwood; Project # NJ000604.0035.0034

Comments:

Executive Summary

A Bio-Trap® Stable Isotope Probing (SIP) study was performed to investigate whether benzene biodegradation is occurring under existing site conditions. Bio-Trap® samplers were baited with ^{13}C labeled benzene and deployed in monitoring wells PMAIR-180 and PMAIR-230. Following a 34 day deployment period, all Bio-Traps were recovered for quantification of ^{13}C incorporation into biomass and dissolved inorganic carbon (DIC). A complete summary of the results is provided in Table 1.

- All monitoring wells demonstrated biodegradation of benzene under existing site conditions.
    - Despite no detection of phenol hydroxylase (PHE) expression, incorporation of ^{13}C labeled benzene into biomass occurred at both monitoring wells.
    - Both monitoring wells exhibit low total PLFA biomass and low ^{13}C labeled benzene incorporated biomass.
        - Well PMAIR-180 total biomass was 3.02E+04 cells/bead and ^{13}C labeled benzene incorporated biomass was 2.82E+02 cells/bead.
        - Similarly, well PMAIR-230 total biomass was 36.06E+04 cells/bead and ^{13}C labeled benzene incorporated biomass was 6.54E+02 cells/bead.
    - However, both monitoring wells also exhibit moderate PLFA del values, indicating moderate incorporation of ^{13}C labeled benzene into biomass present.
        - Well PMAIR-180 average PLFA Del value was 401.
        - Well PMAIR-230 average PLFA Del value was 256.

- Dissolved inorganic carbon $\%^{13}C$ values indicate ^{13}C labeled benzene is being incorporated into respiration processes (mineralization) at both monitoring wells under existing site conditions.
    - Well PMAIR-180 DIC $\%^{13}C$ value shows moderate incorporation into mineralization (1.40%).
    - Well PMAIR-230 DIC $\%^{13}C$ value was 1.10% showing slightly lower incorporation into mineralization.

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Overview of Approach

Stable Isotope Probing (SIP)

Stable isotope probing (SIP) is an innovative method to track the environmental fate of a "labeled" contaminant of concern to unambiguously demonstrate biodegradation. Two stable carbon isotopes exist in nature – carbon 12 (^{12}C), which accounts for 99% of carbon and carbon 13 (^{13}C), which is considerably less, abundant (~1%). With the SIP method, the Bio-Trap® sampler is baited with a specially synthesized form of the contaminant containing ^{13}C labeled carbon. Since ^{13}C is rare, the labeled compound can be readily differentiated from the contaminants present at the site. Following deployment, the Bio-Trap® is recovered and three approaches are used to conclusively demonstrate biodegradation of the contaminant of concern.

- The loss of the labeled compound provides an estimate of the degradation rate (% loss of ^{13}C).
- Quantification of ^{13}C enriched phospholipid fatty acids (PLFA) indicates incorporation into microbial biomass.
- Quantification of ^{13}C enriched dissolved inorganic carbon (DIC) indicates contaminant mineralization.

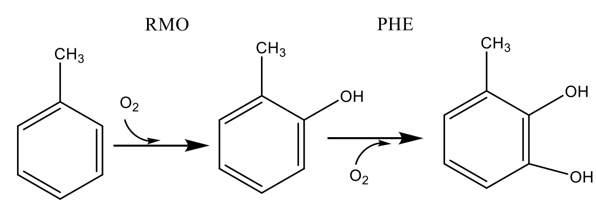
Phospholipid Fatty Acids (PLFA): PLFA are a primary component of the membrane of all living cells including bacteria. PLFA decomposes rapidly upon cell death (1, 2), so the total amount of PLFA present in a sample is indicative of the viable biomass. When combined with stable isotope probing (SIP), incorporation of ^{13}C into PLFA is a conclusive indicator of biodegradation.

Some organisms produce "signature" types of PLFA allowing quantification of important microbial functional groups (e.g. iron reducers, sulfate reducers, or fermenters). The relative proportions of the groups of PLFA provide a "fingerprint" of the microbial community. In addition, *Proteobacteria* modify specific PLFA during periods of slow growth or in response to environmental stress providing an index of their health and metabolic activity.

CENSUS

Based on quantitative polymerase chain reaction (qPCR), CENSUS is a nucleic acid-based approach to quantify specific microorganisms, groups of microorganisms, or functional genes involved in bioremediation or other biological processes. CENSUS targets include bacteria and functional genes responsible for biodegradation of chlorinated solvents and petroleum products among others.

- **Phenol Hydroxylase (qPHE):** Phenol hydroxylase catalyzes the continued oxidation of phenol and cresol intermediates. In single compound microcosm studies, PHE was detected following amendment with naphthalene (in addition to microcosms containing benzene, toluene, *p*-xylene, and biphenyl) suggesting a role in the biodegradation of numerous aromatic compounds or their metabolites.



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Results

Table 1. Summary of the results obtained from the Bio-Trap® Units. Interpretation guidelines and definitions are found later in the document.

Sample Name	PMAIR-180	PMAIR-230
mRNA (gene copies/bead)		
Phenol Hydroxylase (PHE)	<5.00E+01	<5.00E+01
Contaminant Loss (µg/bd)		
Benzene Pre-deployment	135 ± 14	135 ± 14
Benzene Post-deployment	144 ± 13	139 ± 20
Biomass & ^{13}C Incorporation		
Total Biomass (Cells/bd)	3.02E+04	6.06E+04
^{13}C Enriched Biomass (Cells/bd)	2.82E+02	6.54E+02
Average PLFA Del (‰)	401	256
Maximum PLFA Del (‰)	614	432
^{13}C Mineralization		
DIC Del (‰)	256	30.3
DIC % 13C	1.40%	1.10%
Community Structure (% total PLFA)		
Firmicutes (TerBrSats)	1.65	4.58
Proteobacteria (Monos)	56.0	63.2
Anaerobic metal reducers (BrMonos)	0.0	6.9
Actinomycetes (MidBrSats)	0	0
General (Nsats)	42.4	25.3
Eukaryotes (Polyenoics)	0.0	0.0
Physiological Status (Proteobacteria only)		
Slowed Growth	0.00	0.87
Decreased Permeability	0.00	0.00

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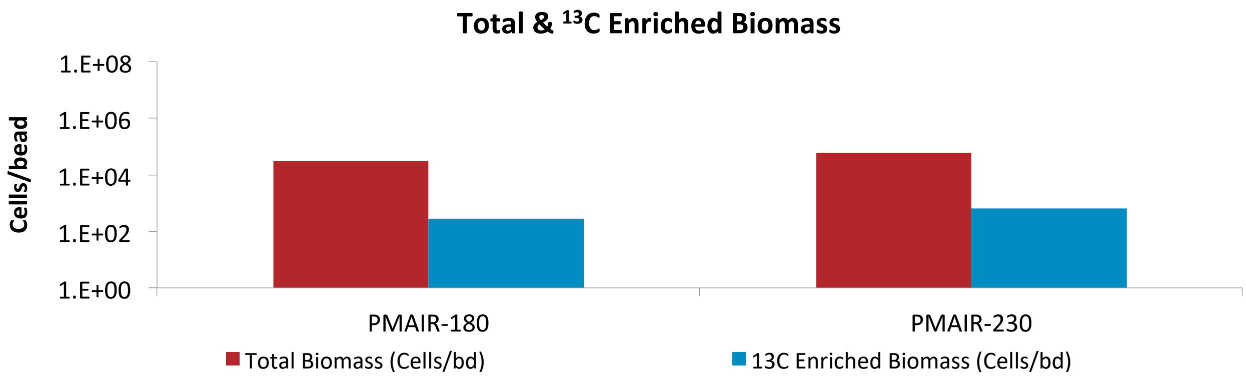

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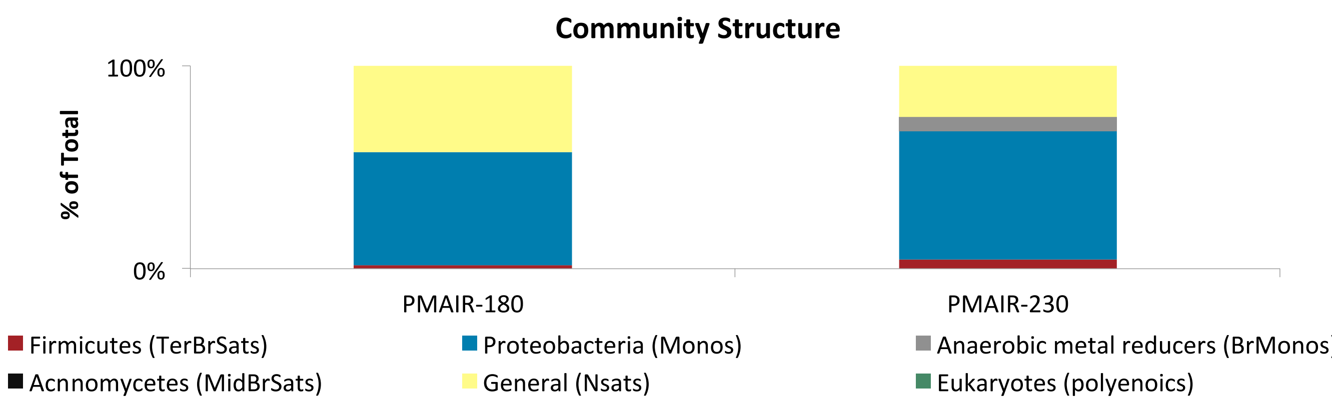

Figure 2. Relative percentages of total PLFA structural groups in the samples analyzed. Structural groups are assigned according to PLFA chemical structure, which is related to fatty acid biosynthesis. See the table in the interpretation section for detailed descriptions of the structural groups.

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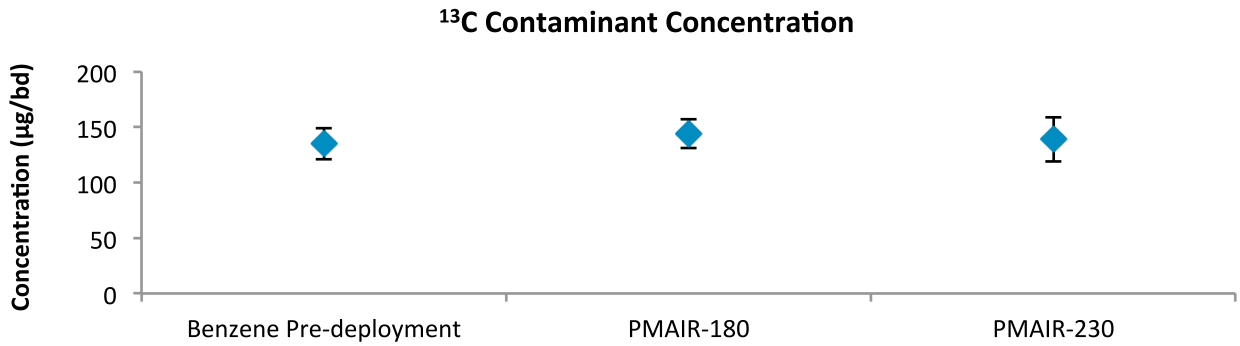

Figure 3. Comparison of Pre-deployment concentrations loaded on Bio-Sep beads to the concentrations detected after incubation

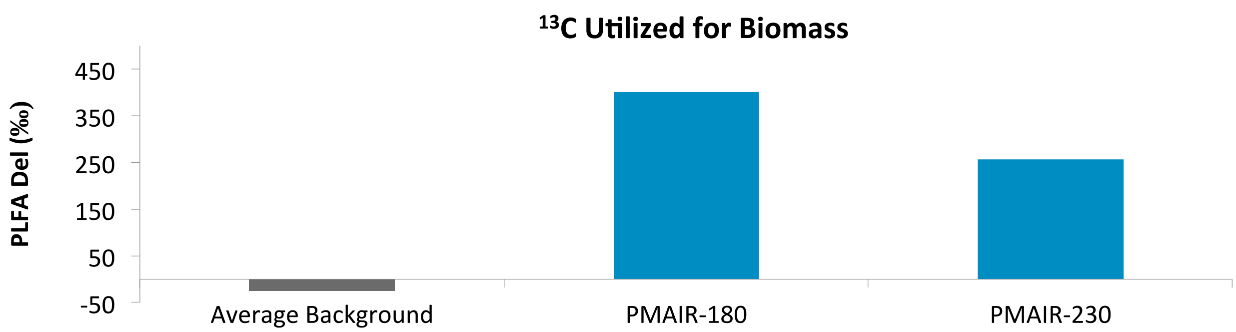

Figure 4. Comparison of the average Del value obtained from PLFA biomarkers from each Bio-Trap® unit to the average background Del observed in samples not exposed to ^{13}C enriched compounds.

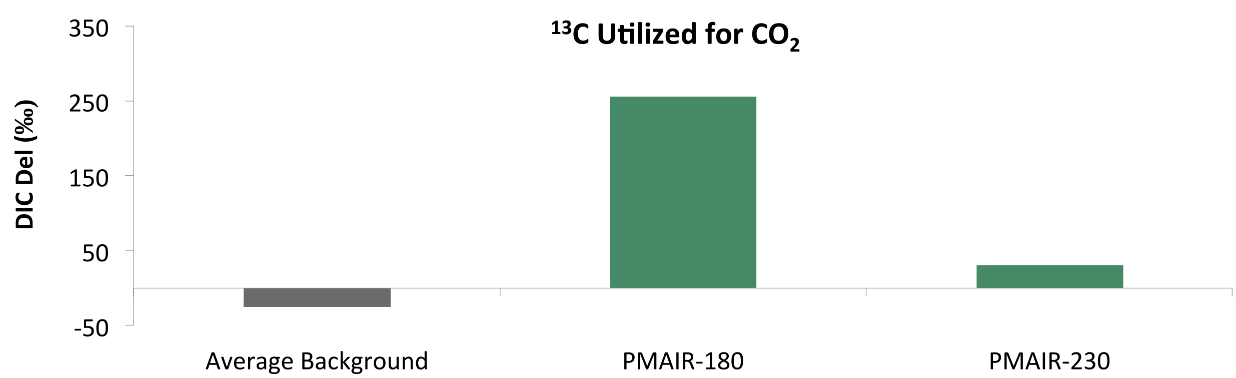

Figure 5. Comparison of the Del value obtained from DIC from each Bio-Trap® unit to the average background Del observed in samples not exposed to ^{13}C enriched compounds.

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Interpretation

Interpretation of the results of the SIP Bio-Trap® study must be performed with due consideration of site conditions, site activities, and the desired treatment mechanism. The following discussion describes interpretation of results in general terms and is meant to serve as a guide.

Contaminant Concentration: Bio-Traps® are baited with a ^{13}C labeled contaminant of concern and a pre-deployment concentration is determined prior to shipping. Following deployment, Bio-Traps® are recovered for analysis including measurement of the concentration of the ^{13}C labeled contaminant remaining.

Biomass Concentrations: PLFA analysis is one of the most reliable and accurate methods available for the determination of viable (live) biomass. Phospholipids break down rapidly upon cell death, so biomass calculations based on PLFA content do not include "fossil" lipids from dead cells. Total biomass (cells/bead) is calculated from total PLFA using a conversion factor of 20,000 cells/pmole of PLFA. When making comparisons between wells, treatments, or over time, differences of one order of magnitude or more are considered significant.

	Total Biomass	
Low	**Moderate**	**High**
10^3 to 10^4 cells	10^5 to 10^6 cells	10^7 to 10^8 cells

For SIP studies, the ^{13}C enriched PLFA is also determined to conclusively demonstrate contaminant biodegradation and quantify incorporation into biomass as a result of the ^{13}C being used for cellular growth. The % ^{13}C incorporation (^{13}C enriched biomass/total biomass) is also provided in the data summary table, but the value must be interpreted carefully especially when comparing wells or treatments. Typically, biodegradation of a contaminant of concern is performed by a small subset of the total microbial community. For Bio-Traps® with large total biomass, the % ^{13}C incorporation value could be low despite significant ^{13}C labeled biomass and loss of the compound. The % ^{13}C incorporation should be viewed in light of total biomass, percent loss, and dissolved inorganic carbon (DIC) results.

^{13}C enrichment data is often reported as a del value. The del value is the difference between the isotopic ratio ($^{13}C/^{12}C$) of the sample (R_x) and a standard (R_{std}) normalized to the isotopic ratio of the standard (R_{std}) and multiplied by 1,000 (units are parts per thousand, denoted ‰).

R_{std} is the naturally occurring isotopic ratio and is approximately 0.011180 (roughly 1% of naturally occurring carbon is ^{13}C). The isotopic ratio, R_x, of PLFA is typically less than the R_{std} under natural conditions, resulting in a del value between -20 and -30‰. For a SIP Bio-Trap® study, biodegradation and incorporation of the ^{13}C labeled compound into PLFA results in a larger $^{13}C/^{12}C$ ratio (R_x) and thus del values greater than under natural conditions. Typical PLFA del values are provided below.

	PLFA Del (‰)	
Low	**Moderate**	**High**
0 to 100	100 to 1,000	>1,000

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Dissolved Inorganic Carbon (DIC): Often, bacteria can utilize the ^{13}C labeled compound as both a carbon and energy source. The ^{13}C portion used as a carbon source for growth can be incorporated into PLFA as discussed above, while the ^{13}C used for energy is oxidized to $^{13}CO_2$ (mineralized).

^{13}C enriched CO_2 data is often reported as a del value as described above for PLFA. Under natural conditions, the R_x of CO_2 is approximately the same as R_{std} (0.01118 or about 1.1% ^{13}C). For an SIP Bio-Trap® study, mineralization of the ^{13}C labeled contaminant of concern would lead to a greater value of R_x (increased $^{13}CO_2$ production) and thus a positive del value. As with PLFA, del values between 0 and 100‰ are considered low, values between 100 and 1,000‰ are considered moderate, and values greater than 1,000‰ are considered high. Thus DIC %^{13}C are considered low if the value is less than 1.23%, moderate if between 1.23 and 2.24%, and high if greater than 2.24%.

Dissolved Inorganic Carbon (DIC) Del and %^{13}C		
Low	**Moderate**	**High**
0 to 100	100 to 1,000	>1,000
1.11 to 1.23%	1.23 to 2.24%	>2.24%

Community Structure (% total PLFA): Community structure data is presented as a percentage of PLFA structural groups normalized to the total PLFA biomass. The relative proportions of the PLFA structural groups provide a "fingerprint" of the types of microbial groups (e.g. anaerobes, sulfate reducers, etc.) present and therefore offer insight into the dominant metabolic processes occurring at the sample location. Thorough interpretation of the PLFA structural groups depends in part on an understanding of site conditions and the desired microbial biodegradation pathways. For example, an increase in mid chain branched saturated PLFA (MidBrSats), indicative of sulfate reducing bacteria (SRB) and *Actinomycetes*, may be desirable at a site where anaerobic BTEX biodegradation is the treatment mechanism, but would not be desirable for a corrective action promoting aerobic BTEX or MTBE biodegradation. The following table provides a brief summary of each PLFA structural group and its potential relevance to bioremediation.

Table 2. Description of PLFA structural groups.

PLFA Structural Group	General classification	Potential Relevance to Bioremediation Studies
Monoenoic (Monos)	Abundant in Proteobacteria (Gram negative bacteria), typically fast growing, utilize many carbon sources, and adapt quickly to a variety of environments.	Proteobacteria is one of the largest groups of bacteria and represents a wide variety of both aerobes and anaerobes. The majority of Hydrocarbon utilizing bacteria fall within the Proteobacteria
Terminally Branched Saturated (TerBrSats)	Characteristic of Firmicutes (Low G+C Gram-positive bacteria), and also found in Bacteriodes, and some Gram-negative bacteria (especially anaerobes).	Firmicutes are indicative of presence of anaerobic fermenting bacteria (mainly *Clostridia/Bacteriodes*-like), which produce the H_2 necessary for reductive dechlorination
Branched Monoenoic (BrMonos)	Found in the cell membranes of micro-aerophiles and anaerobes, such as sulfate- or iron-reducing bacteria	In contaminated environments high proportions are often associated with anaerobic sulfate and iron reducing bacteria
Mid-Chain Branched Saturated (MidBrSats)	Common in sulfate reducing bacteria and also Actinobacteria (High G+C Gram-positive bacteria).	In contaminated environments high proportions are often associated with anaerobic sulfate and iron reducing bacteria
Normal Saturated (Nsats)	Found in all organisms.	High proportions often indicate less diverse populations.
Polyenoic	Found in eukaryotes such as fungi, protozoa, algae, higher plants, and animals.	Eukaryotic scavengers will often rise up and prey on contaminant utilizing bacteria

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Physiological Status (*Proteobacteria*): Some *Proteobacteria* modify specific PLFA as a strategy to adapt to stressful environmental conditions (3, 4). For example, *cis* monounsaturated fatty acids may be modified to cyclopropyl fatty acids during periods of slowed growth or modified to *trans* monounsaturated fatty acids to decrease membrane permeability in response to environmental stress. The ratio of product to substrate fatty acid thus provides an index of their health and metabolic activity. In general, status ratios greater than 0.25 indicate a response to unfavorable environmental conditions.

Glossary

Del: A Del value is the difference between the isotopic ratio ($^{13}C/^{12}C$) of the sample (R_x) and a standard (R_{std}) normalized to the isotopic ratio of the standard (R_{std}) and multiplied by 1,000 (units are parts per thousand denoted ‰).

$$Del = (R_x - R_{std})/R_{std} \times 1000$$

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